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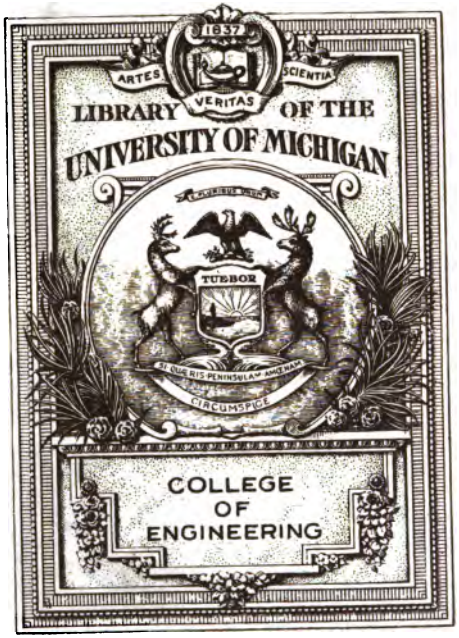
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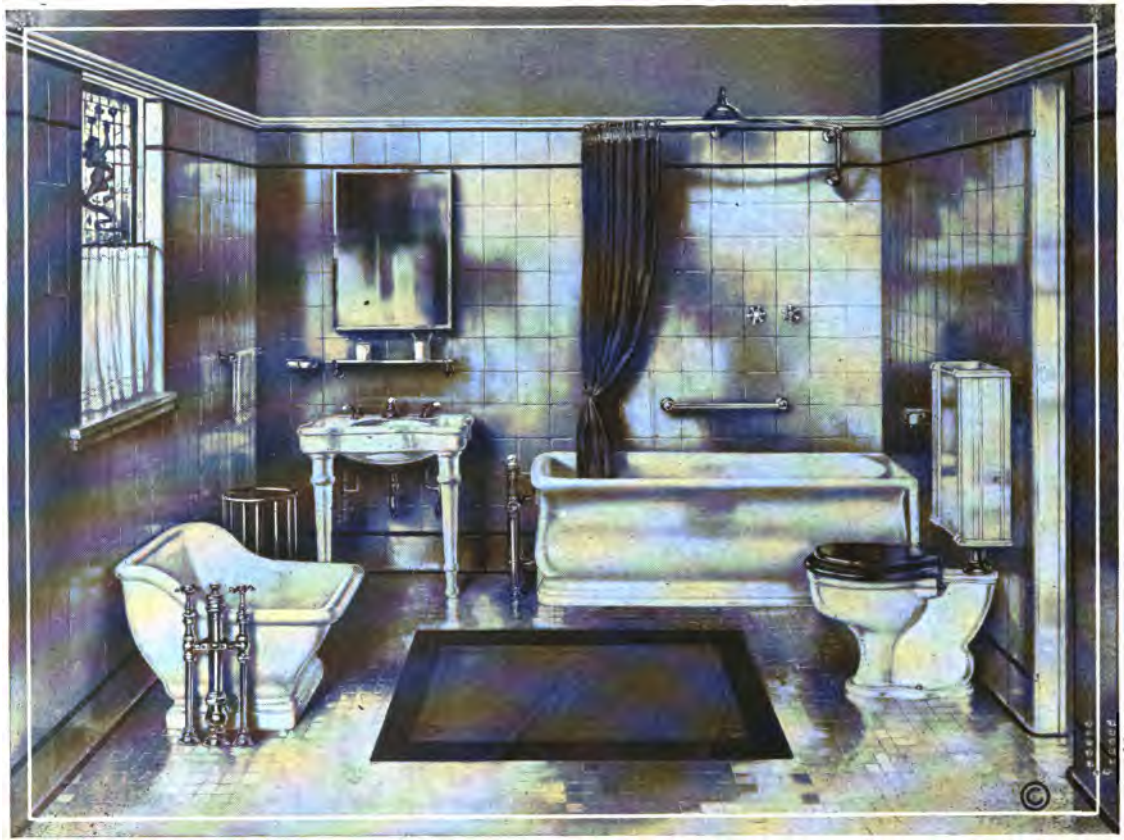

A TYPICAL MODERN BATH-ROOM

Sanitary, Heating, *and* Ventilation Engineering

A General Reference Work

ON HYDRAULICS, MUNICIPAL WATER SUPPLY, DOMESTIC HOT WATER SUPPLY, HOUSE DRAINAGE AND VENTING, SANITATION METHODS, SEWAGE DISPOSAL SYSTEMS, HEATING AND VENTILATION, AND MANAGEMENT OF SANITARY ENGINEERING BUSINESS, INCLUDING MAKING ESTIMATES AND CONTRACTS

Prepared by a Corps of

SANITARY EXPERTS, CONSULTING ENGINEERS, AND SPECIALISTS OF THE HIGHEST PROFESSIONAL STANDING

Illustrated with over One Thousand Engravings

FOUR VOLUMES

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Grateful acknowledgment is here made also for the invaluable co-operation of the foremost Engineering Firms and Manufacturers in making these volumes thoroughly representative of the latest and best practice in every branch of the broad field of Heating, Plumbing, and Sanitation; also for the valuable drawings, data, suggestions, criticisms, and other courtesies.

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EAST END OF COLON HOSPITAL GROUNDS, SHOWING NURSES' HALL AND PHYSICIANS' QUARTERS

These carefully constructed buildings are only one feature of the wonderful sanitary campaign which made the Canal Zone a safe place for the workmen in marked contrast to the experiences of the French Canal Company.

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TENTH STREET, COLON, BEFORE CLEANING AND PAVING

Foreword

HISTORICAL records tell us that sanitation began with the civilization of man, and we find from Biblical records that Moses enunciated some forms of such, but never in the history of the world has so much attention been given to the sanitary conditions of municipalities as has characterized the past few years. Not a day passes but that brings to light new efforts on the part of the public officials and commercial enterprises of various kinds in behalf of public welfare.

¶ Every community and every individual with a semblance of progress is now engaged in one form or other of sanitary investigations and improvement. They realize that these professions are absolutely indispensable to civilization and now appreciate the untold value of pure air, pure water, the convenience and comfort of an adequate domestic hot water supply, modern sanitary fixtures, good drainage, sewerage, and sewage disposal, proper systems of steam, hot air, hot water and vapor heating, and speedy and efficient garbage collection and disposal.

¶ This is an age of new things. Present progress is just the beginning of what may be anticipated in these professions in the coming years. The enormous increase in population and the crowding together of masses of people on small areas have made our work very complex; so that whereas we used to speak of *Sewage Disposal* — which really means getting rid of the sewage — we are now concentrating our thoughts on *Sewage Purification.* The same statement applies to *Water Supply,* for a pure source can rarely be found these days, so we turn our attention to *Purified Water.* Again, the term *Garbage Disposal* interests us no longer, and we now do our utmost *to destroy* the garbage as quickly as possible without nuisance.

¶ Sanitary engineering can boast of wonderful scientific accomplishments and has rightly been termed "The Handmaid of Civilization." It enabled the Panama Canal to be built by eliminating yellow fever from the Canal Zone. It banished the deadliest enemy—Disease—in the European War, and lowered the death rate during the past sixty years by sixty per cent.

¶ All factory, office, and store managers now realize that there can be no efficiency in their stores or plants unless a perfect system of heating and ventilation is in existence. One of our largest mercantile concerns compiled statistics to ascertain the amount of money they were losing through colds contracted by their employes. It cost the firm twenty-five dollars every time one of their employes caught cold, and colds are brought about by inefficient ventilation.

¶ Another large concern in Baltimore rented a new and modern building which was looked upon as the acme of perfection. During the first two winters, twenty-seven per cent of the employes were ill. An efficiency expert was called in, who discovered defects in the heating and ventilation system. When these defects were rectified, the sickness fell to seven per cent, or a reduction of nearly four times.

¶ Notwithstanding the truly wonderful progress and splendid improvements made in these professions the past few years, there are countless and stupendous opportunities for us to do beneficial and noble work at this time.

¶ There are over twenty million buildings in the United States —millions of them with antiquated plumbing, and millions of others that have no plumbing whatever. Again, there are six-and-one-half millions of a type that should be radiator heated. Of the number already heated, ninety per cent are prospects for improvements in the efficiency of their heating plants.

¶ Quite recently a State Board of Health made a survey of the agricultural counties to ascertain the relation that prevails between health and farm sanitation, and they classed 206 farm houses sanitary, and 1068 unsanitary, and similar conditions exist in every rural district. However, the communities in these districts now realize that they can have in their homes all the modern sanitary appliances, which give them comfort and convenience previously undreamed of.

¶ In conclusion, let us say that all those entering upon or actually engaged in the sanitary, heating, and ventilation professions should realize the magnitude and importance of the work, their responsibilities to the community, and the necessity for continual study of these most important subjects.

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MODERN BATHROOM SHOWING EXCELLENT ARRANGEMENT OF FIXTURES IN SMALL SPACE

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SANITARY APPLIANCES

TRAPS

Object of Traps. There are endless varieties of traps marketed, and each shape and type may have some particular advantage for the purpose it is used.

Broadly, we can define a trap as a device holding a quantity of water and having an upper portion which dips into the water and forms the seal.

The seal should be at least 1½ inches in depth for traps up to 2 inches in diameter and may be 2½ inches deep for water closets and the large traps.

The object of the trap is to cut off from the interior of the building, by means of the water seal, the foul gases which are ever present in soil and waste pipes. To accomplish this object satisfactorily, a trap must be placed immediately under every sanitary fixture and the water seal of such trap must be kept intact, otherwise the occupants of a house may be placed in a position of false security, thinking no foul gases can pass the trap, yet the seal may be broken and dense volumes of obnoxious gases enter into and pollute the entire building.

Characteristics of Good Trap. A good trap embraces the following features: It should be free from all sharp angles and corners in which foul matter may collect or, in other words, it must be perfectly self-cleansing. It must have a good depth of water seal, yet contain only a minimum quantity of water. It must be constructed of a material which will not be acted upon by sewage or foul gases in the trap and that can be joined readily to both the sanitary fixture and the waste pipe.

Methods by Which Water Seal May Be Broken. The seal of a trap may be broken by five distinct methods, namely, evaporation, momentum, capillary attraction, leakage, and siphonage.

Evaporation. The trap seal is broken by evaporation by the drying-up of the water seal in the trap, due to the passing away of the water in the form of invisible vapor. This process

of evaporation is forever taking place not only in traps but on a large scale. All surface water, which includes the ocean, lakes, rivers, etc., is being constantly evaporated to form the clouds which produce the rainfall. To avoid the seal being broken by evaporation, the fixtures should be used periodically; or the trap should be filled with oil—an expensive method if there are a large number of traps in the building; or they may be filled with a strong salt solution. This difficulty occurs only in those buildings which are unoccupied for considerable periods or in basements or cellars where drain traps are unobserved or forgotten. For the latter an anti-siphon mechanical trap may be used.

Momentum. The water seal of a trap may be broken also by momentum, especially if the trap is of round pipe construction and badly shaped. The result of the latter is that the trap may have a small depth of water seal and yet contain a large quantity of water, having what is termed an easy flow through it. The sudden discharge of a large quantity of water from a considerable height will cause the water to attain such a velocity in its passage through the trap that only a small amount will be retained in the trap, thus breaking the seal. In the case of very high buildings, the force of the wind blowing over the terminal of the vent shaft and then suddenly changing its direction, as is often the case in squally weather, sets up oscillations so that the momentum of the moving water will occasionally break the trap seal.

Capillary Attraction. Capillary attraction is the action which causes the oil to rise in a lamp wick or causes blotting paper to absorb ink. Should a piece of rag, string, or lint catch on the outlet side of the trap and have one end of this material in the seal of the trap, the water will be drawn up along this string and allowed to flow down the soil or waste pipe. In a remarkably short time the seal will be broken. A practical experiment may be tried by the reader by procuring a glass and filling it with water. Now take a piece of ordinary darning cotton and place it in the water, allowing one end to hang over and below the outside of the glass. In a short time the glass will be emptied of water.

Leakage. The trap seal may be broken also through leakage. A leaky connection on a drum trap, a sand hole in a cast-brass

trap, or a defective packing around the trap screw will speedily break the seal. The seal of traps with weirs may also be broken by leakage. The water weir may be imperfect and the seal leak into the waste pipe without betraying the defect by outward leakage.

Siphonage. Traps introduce into plumbing the element of siphonage. This may be normal and desirable, as in the case of closets which discharge their contents by siphonic action, but undesired siphonage in fixture traps and the means of preventing it are prime factors in every plumber's work.

Ordinary siphonage can best be illustrated by a few simple diagrams showing the principles involved. In Fig. 1 is shown a

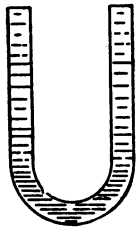


Fig. 1. U-Tube with Legs of Equal Length

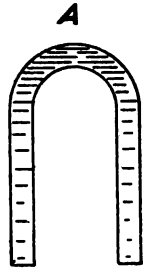


Fig. 2. U-Tube Inverted

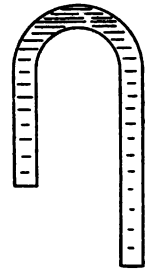


Fig. 3. Inverted U-Tube with Legs of Unequal Length

U-tube with legs of equal length filled with water. If we invert the tube, as shown in Fig. 2, the water will not run out, because the legs are of equal length and contain equal weights of water, which will pull downward from the top with the same force, tending to form a vacuum at *A*. Cohesion of the particles of water, together with equal atmospheric support of the water at the open ends of the tube, prevents any appreciable void space when the U is of short length. If one of the legs is lengthened, Fig. 3, so that the column of water is heavier on one side than on the other, the water will run out. The atmospheric pressure being practically equal on both legs, the greater weight of the water in the long end, through cohesion, pulls the water in the shorter tube up over the bend, in much the same way as an unbalanced chain would run over a pulley. The columns

of water in the tube in this case may be likened to a piece of rope hanging over a pulley; when equal lengths hang on each side, it will remain stationary; but if one end is longer and therefore heavier than the other, the whole rope will be drawn over by the longer and heavier portion.

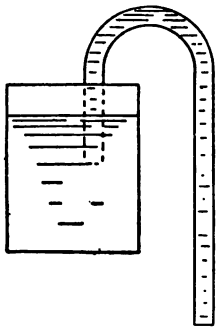


Fig. 4. A Common Siphon.

If the short leg, Fig. 3, be dipped in a vessel of water, as shown in Fig. 4, we then have the conditions necessary to form a common siphon. The atmospheric pressure, which before acted on the water at the bottom of the short leg of the tube, now becomes operative on the surface of the water in the vessel, and the flow through the tube will continue until the water-level in the vessel falls slightly below the end of the tube, admitting air and breaking the siphonic action. Gravity acts proportionally on the water of both legs of the U during siphonage, and the point of tension is therefore at the highest point of the bend.

If the bend should be pierced at the top, air-pressure would be established at both ends of each leg, and gravity would instantly empty the short leg into the vessel. It is in this manner that a crown vent to a common fixture trap breaks the flow and throws enough

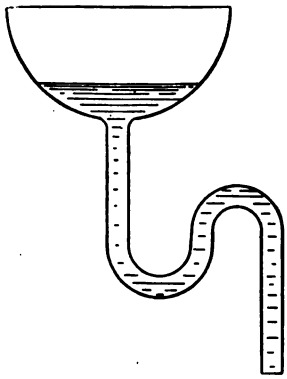


Fig. 5. Trap Fulfilling Siphonage Conditions.

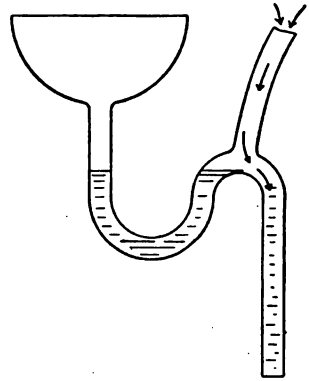


Fig. 6. Siphoning of Trap Broken by Crown Vent.

water back into the body of the trap to preserve the water-seal. Fig. 5 shows the principle of Fig. 4 applied to the trap of a plumbing fixture. If the bowl is well filled with water, so that when the stopper

is removed from the bottom, the waste pipe for some distance below the trap will be filled with a solid column of water, siphonic action like that just described will take place and the trap will be drained. A sufficient amount of water runs down from the fixture and sides of the pipe above the trap to partially provide for the seal, its full restoration being assured when a crown vent is used, by water being thrown back from the short leg of the siphon (center leg of the trap) as shown in Fig. 6.

The direct action of the water of a fixture in breaking its own trap seal by siphonage, is called *self-siphonage.* A more common form of trap siphonage in defective work, is where two or more fixtures connect with the same waste pipe, as shown in Fig. 7. In such cases, the seal of the lower fixture is more apt to be broken by the discharge of the upper. The falling column of water leaves behind it a partial vacuum in the soil pipe; and the outer air tends to rush into the pipe through the way of least resistance, which is often through the trap seal of the fixture below. The friction of the rough sides of a tall soil-pipe, even though it be open at the roof, opposed to the flow of air through it, will sometimes offer more resistance than the trap seals of the fixtures, with the result that the seals are broken, and gases from the drain are free to enter the building.

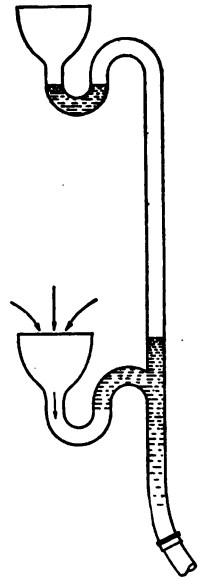


Fig. 7. Two Unvented Fixtures Connected to Same Waste Pipe, Causing Self-Siphonage.

Kinds of Traps. The kinds of fixture traps are innumerable. They can be divided into two general classes—those that seal with *water only,* and those that have a *mechanical seal* as an adjunct to that of the water. These may be again divided into *plain* and *anti-siphoning* classes.

The trap having no concealed partitions and with all its walls exposed to view, is best. If the water leaks through the wall, its defectiveness is evident, and the annoyance from the leak suggests repairing.

Of the simple *water-seal* fixture traps, the open-walled *drawn lead* is used for ordinary work. It can be had with equal-length arms or with extended inlet or outlet, so as to reach from fixture to floor or

wall without a piece of intermediate pipe. The form shown by full lines in Fig. 8 represents a full "S" pattern. When the ends are bent as per dotted lines *A* and *C*, the trap is called a *running* trap;

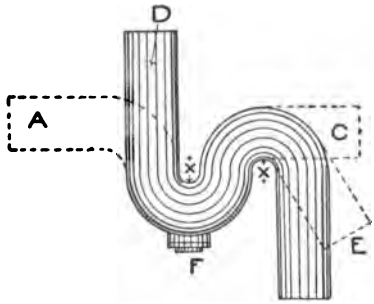


Fig. 8. "S"-Pattern Trap.

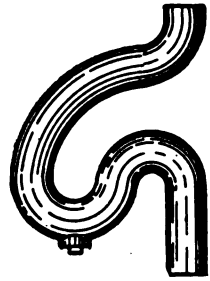


Fig. 9. A Bag Trap.

when the ends are at *D* and *C*, it is said to be a *half-S* or *P* trap; when the ends are set as at *D* and *E*, it is called a $\frac{3}{4}$-*S* trap. *F* is a clean-out screw for emptying and cleansing. The distance represented by *X* should, in a trap for ordinary purposes, be $\frac{1}{2}$ to 2 inches, according to size. Frequently this distance, which constitutes the water-lock, is much reduced; and sometimes the trap is unsealed by the plumber stretching its bends in order to reach some faulty roughing-in.

In buildings where the plumbing may be left unused for weeks from time to time, as is likely in rented houses, *deep-seal* traps, or those with mechanical seals also, should be used. This point is not so important in detached houses or those rented to one family only at a time, since, when a family moves out, there is no one to suffer. But in flat buildings, where some of the flats may be vacant for a time sufficient for an ordinary seal to be broken while other families are living in the house, deep-seal traps are more essential.

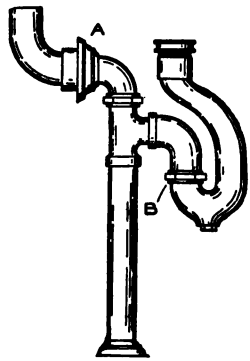


Fig. 10. Open-Wall Trap, Partly Cast.

Fig. 9 shows what is termed a *bag trap*, made to bring the inlet and outlet in the same vertical line. These traps are interchangeable with any others with straight-line outlet—for instance, as shown in Fig. 12.

An open-wall trap partly cast and partly tubing, generally made

of brass, is shown in Fig. 10; the vent connection to wall being at *A*. This form of trap generally has a swivel-joint at *B*, which is below the water line, so that the body may be swiveled to meet roughing-in openings in any direction within two diameters of the line of fixture outlet. The bag form shown is most convenient for D-shape or standing waste bowls which present the outlet comparatively near the wall. The regular "S" of this type suits bowls with center outlet, and will reach a wider range of variation in roughing-in.

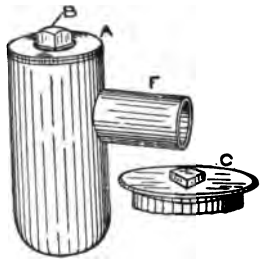


Fig. 11. Common Lead Drum or Pot Trap.

Fig. 11 shows a common lead drum or pot trap, most convenient to the plumber. It is furnished without openings, and the plumber makes bends, and wipes-in his inlet and outlet at points in the circumference most convenient to reach the fixture opening. *A* is the screw-top clean-out; and *B*, the wrench-face for turning it. The trap is furnished, when desired, with nickel-plated brass flanged cover, as shown at *C*, to screw on at the floor-level. *F* is ordinarily the outlet, the inlet being wiped-in near the bottom to give it the water-lock. This is not proper, however, as it puts the sewer air against the clean-out cover, which might leak gases into the building without betraying any evidence of its defectiveness by water leakage. To be strictly correct, *F* should be the inlet; and the outlet, in the shape of an offset, or that of an inverted P-trap without the trap-screw, should be wiped-in near the bottom in a way to retain the proper seal and thus bring the sewer air against the water-seal instead of the clean-out cover.

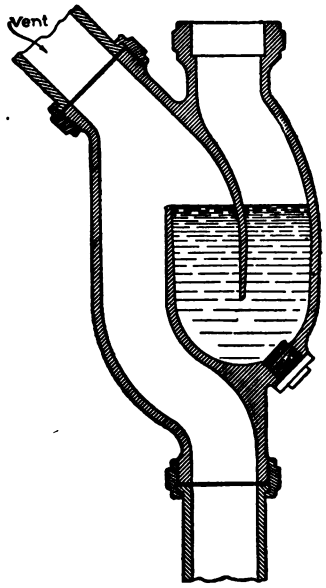


Fig. 12. Section of Flask or Atlas Trap, with Two Interior Weirs.

Traps that retain their seals by means of interior weirs are of doubtful character, even at their best; none but well-tested cast-brass

traps of such a pattern should ever be installed. Fig. 12 is a section of a *flask* or *Atlas* trap, with vent, usually made of cast brass and depending upon two interior weirs to form the seal, one retaining the water, and the other dipping into the water to prevent sewer air from getting into the house through the fixture. If the water weir of such a trap becomes defective, there is no evidence except odors by which the occupants may discover it. If the dipping weir is defective the value of the water seal is *nil*. In either case the trap is no barrier to the admission of drain air to the house.

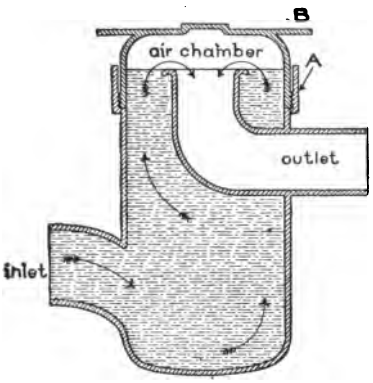


Fig. 13. Bath Trap with Submerged Inlet.

Fig. 13 illustrates a form of trap suitable for use with baths. It has a submerged inlet connection which is expanded so that the flow enters the trap at a dipping angle which produces a swirl with cleansing effect. The extension collar *A* is made so that the screw-cover *B* forms the gasket joint below the water-level. The method of providing the outlet in this trap makes it open to the same objection raised in connection with Fig. 11. This form, however, has the merit of being accessible for inspection without disturbing its service, which is impossible with the flask pattern shown in Fig. 12.

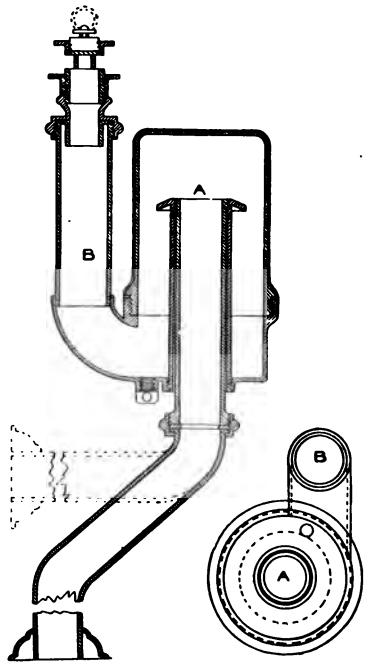


Fig. 14. Lavatory Trap with Interior Flanged Weir. Weir is Double-Walled to Betray Leakage.

The lavatory trap shown in Fig. 14, has an interior weir as shown at *A*; but the wall is doubled in such a way as to betray defectiveness by water leakage. It is made of cast metal, and is furnished

with either glass or metal dome. The strong point claimed for this trap is the cleansing effect obtained by the flange extension of the exit, as shown at *A*, deflecting some of the water, which, together with the swirling effect produced by the tangential inlet, makes the trap self-cleansing.

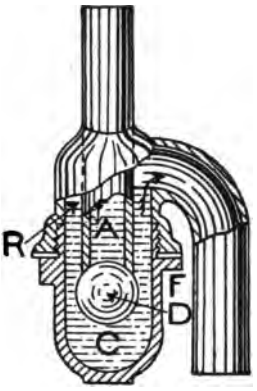


Fig. 15. Trap with Mechanical Seal Acting by Flotation.

Of the traps having a mechanical seal supplementing the water-lock, Fig. 15 is a specific type. The mechanical valve *D* is a rubber ball, lighter than an equal bulk of water, playing in the cup *C*. It acts by flotation, and presses up against the inlet *A* with a force equal to the difference in weight of the ball and the water it displaces. The body is generally made of lead; and the cup of glass, with screw-joint and gasket at *F*. This trap is proof against backwater; and, in case the waste line becomes choked below, will prevent a fixture from flooding even when others are discharged at a higher level. It has, however, several faults that counterbalance its merits. The inlet is open to the same criticisms that an interior wall of any other trap would be; the annular space at *R* accumulates filth; and the mechanical seal is worthless when most needed—that is, in the absence of the water-seal.

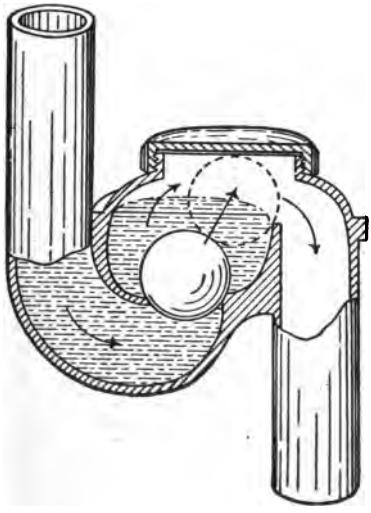


Fig. 16. Trap with Mechanical Seal Acting by Gravity.

Another mechanical seal trap, shown in Fig. 16, is the exact opposite of the previous example. The ball sinks by gravity, and effects a mechanical seal even when the water seal is absent. This trap is not so easily siphoned as a plain trap. It has a clean-out screw, and can be had with vent opening. Air from the sewer side acts against the clean-out cap through which access is had to the ball, and there are interior walls to become defective with little chance of discovery in practice.

A combined mechanical and water-seal trap, is shown in Fig. 17, in which *D* is a hollow, flexible ball inclosing a metal ball D^1, thus giving a resilient seating surface that finds its place by gravity in water. The arrangement is proof against back-water, and the mechanical seal is positive without the aid of water. *A* represents the basin; *B*, the basin coupling; *C*, the valve seat; *F*, a glass cylinder body; and *GG*, a clamp with thumb-screw G^1, for clamping the cylinder body in place. This trap holds a large amount of water, and is not likely to become unsealed from lack of use, as part of the seal is protected by the ball, and should the water evaporate, the mechanical seal is still effective. There are no interior walls through which the trap could lose its seal without betraying the fact by leakage. Generally speaking, mechanical seals in fixture traps cannot be depended upon.

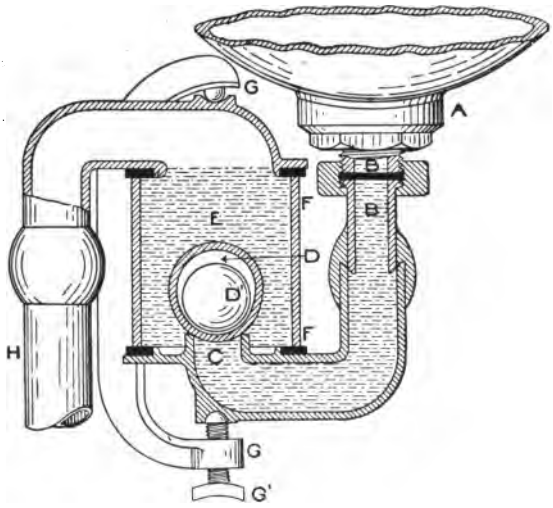


Fig. 17. Trap with Combined Water-Seal and Gravity-Acting Mechanical Seal.

Anti-siphoning traps are a blessing in instances where pipe ventilation is difficult. It would be better to have none of them, however, than to attempt to supplant pipe ventilation by their use to any great extent.

It would be impossible here to consider the whole list of traps individually in an adequate manner. What has been said should be enough to enable one by careful study to decide each case intelligently upon its merits. Many special traps are deserving of more favor than is generally shown them. It is perhaps the fear on the part of the users of these articles of seeming to indorse the horde of cheap competitive articles that causes many to ignore alike the good and bad. This fear is well grounded. The wolves will creep in if the door is opened at all.

BATH FIXTURES

BATHTUBS

Classification. Bathtubs are a prime factor in plumbing and are made of various materials; they range in length from 4 to 6 feet, and the general shapes are the American, French, and Roman. The American pattern has a rounded bottom, one sloping end and one straight end. The French style has a flat bottom, one sloping end and one straight end. The Roman design has a flat bottom and two sloping ends.

The rims of bathtubs vary from 1½ to 5 inches in width. The larger rims are easy on one in getting in and out of the bath and are often used in lieu of a bath seat.

At one time, bathtubs were made of slate; wooden case lined with lead, zinc, copper, or sheet iron; cast iron painted; stoneware; and marble; but practically all modern tubs are made of cast iron, enameled, with a vitreous glaze fused on the iron; or of solid porcelain, potter's clay properly fired, with a vitreous glaze fired on.

Desirable Features for Bathtubs. The following points should be observed in selecting a bathtub:

It should be made of suitable material.

It should have provision for both filling and emptying rapidly.

It should be an adequate size.

It should be so constructed that all wooden or other casing is dispensed with.

It must have an overflow capable of carrying away the water obtained from both faucets.

All bath wastes must be trapped and vented and the size of the pipes should never be less than 1½ inches. The trap should be placed as close to the fitting as practicable, and provision should be made for cleaning the trap. In many localities, a drum trap provided with a trap screw 4 inches in diameter must be in full view above the floor and vented through a Y or similar fitting, is given preference over the floor or running trap.

Discussion of Types of Bathtubs. The most modern form of the American pattern cast-iron enameled bathtub with waste, overflow, and water supply connections is shown in Fig. 18. The very latest improvement, and one which has come to stay, is the

integral base which does not allow a particle of dust to find its way under the tub.

A fine enameled iron bathtub on the Roman pattern is shown in Fig. 19. It is provided also with integral base and can

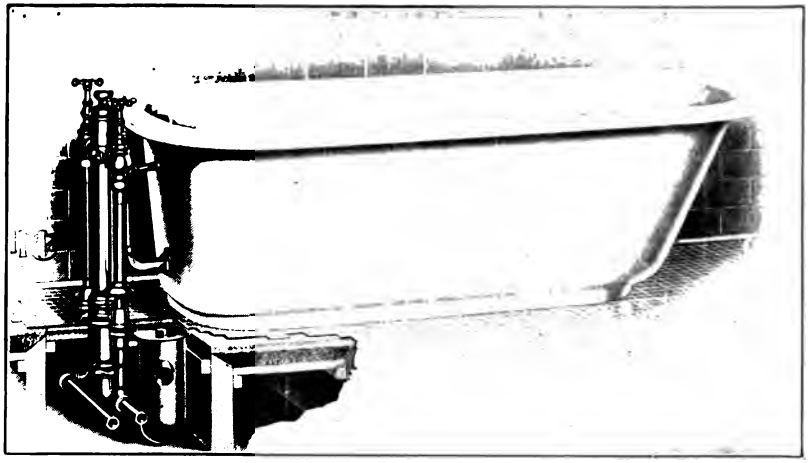


Fig. 18. Enameled-Iron Bathtub with Floor Cut Away to Show Waste, Overflow, and Supply
Courtesy of Federal-Huber Company, Chicago

be placed in either the right or left corner or free from all walls; but the best position, everything considered, is with the fitting side near the wall and not against either end of the room.

Fig. 19. Enameled-Iron Bathtub with Four-Inch Roll Rim. Fixtures Located in Center of Wall Side
Courtesy of Crane Company, Chicago

The solid porcelain tubs are ideal from a sanitary point of view, yet they are very heavy, averaging 1200 pounds each, and occasionally the floor is not capable of supporting them. Further-

more, the porcelain absorbs a tremendous amount of heat, and an efficient domestic hot-water supply must be installed, otherwise the tubs feel cold to the body and the water cools rapidly. These tubs are capable of withstanding considerable rough treatment and can be recommended highly for hotels and public institutions.

The last word in bathtubs from a sanitary standpoint is illustrated in Fig. 20, and embraces every modern feature, being provided with integral base, glazed inside and outside, and made to tile into the walls 1½ inches at the back and both ends. It is made in solid porcelain or porcelain enameled cast iron, and the following are the approximate measurements: length, 5 feet, 5 feet

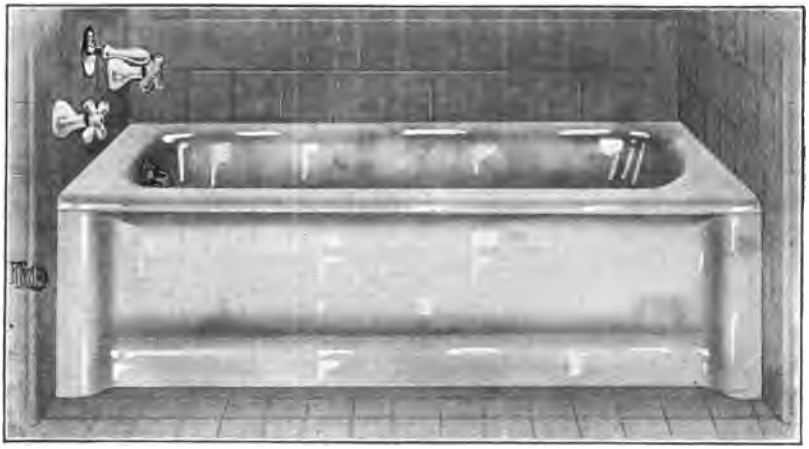


Fig. 20. Set-In Bathtub with Integral Base—Very Modern Equipment
Courtesy of Federal-Huber Company, Chicago

6 inches, or 6 feet; width over all, 30 inches; inside depth, 19 inches; height from floor to top of rim, 21 inches.

SPECIAL BATHS

Shower Baths. At one time, shower or rain baths were used principally in barracks, gymnasiums, schools, etc., but now the public demands both the shower and spray in the toilet rooms.

Many medical men advocate the action of jets or streams of water as the most hygienic method of bathing, for the impact results in stimulating the proper action of the skin and the body does not collect the soap and dirt floating on the surface of the water.

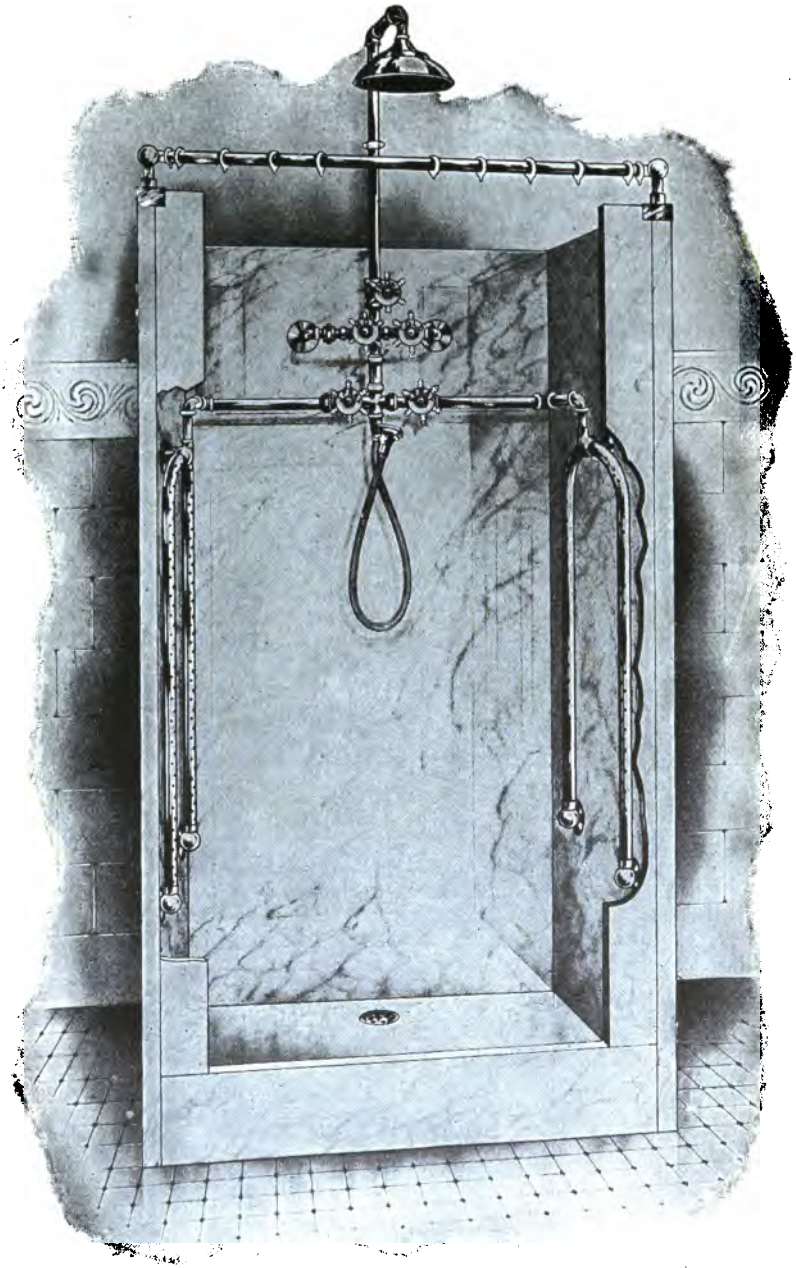


Fig. 21. Nickel-Plated Brass Shower Bath with Slate Cabinet
Courtesy of Federal-Huber Company, Chicago

The older form of showers which direct the water vertically upon the head of the bather are not so desirable as those in which the outlet is inclined and placed at about the level of the shoulders, thus avoiding wetting the head unless desired. Indeed, all the essentials of a bath of this kind are met by a water-supplied rubber tube discharging at about the level of the waist over a tight floor or pan provided with a drain.

Showers, sprays, and rubber hose suitable for attaching to the bathtub faucets can be purchased for about $1.00 in any plumbing or hardware store, while the most elegant shower with mixing

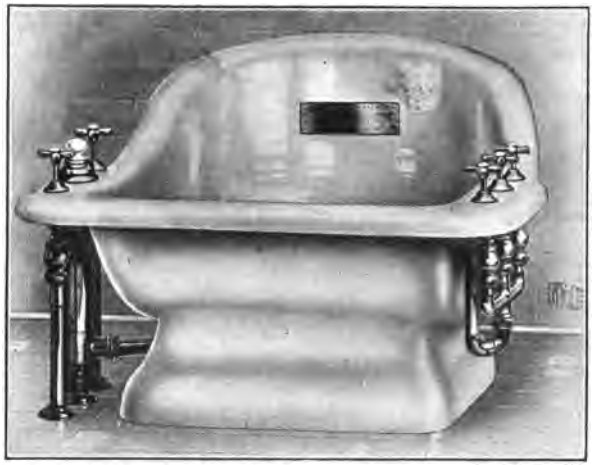


Fig. 22. Typical Sitz Bath
Courtesy of Federal-Huber Company, Chicago

valve, douche, needle spray, rose spray, and shampoo attachment, Fig. 21, can be purchased for $230.00.

A point concerning shower fixtures and relating to the safety of the user, to which special attention should always be given, is that of the valve arrangement. An adequate mixing valve is an essential part of the shower, especially so with the elaborate combinations, otherwise one is liable, inadvertently, to scald himself at first by turning on the hot water alone.

Sitz Baths. Sitz baths are primarily for bathing the hips and loins in a sitting posture but may be fitted with special features if so ordered. Solid porcelain and enameled iron are the usual

materials of construction. The fixtures approximate in dimensions, 15 inches in height at the front, 26 inches at the back, and are about 30 inches wide. In the back, at a proper height, is a horizontal slit accommodation fitting for a liver spray, a wide wave-like spray of water, either hot, cold, or of intermediate temperature, as suits the individual. Fig. 22 shows the latest type of sitz bath with integral base, 3-inch roll rim, china indexed handles, etc., while in the bottom, in conjunction with the outlet, is a hot and cold douche under control of the user. In the center of the douche, and operated independently, is a bidet jet, making the fixture exceedingly useful.

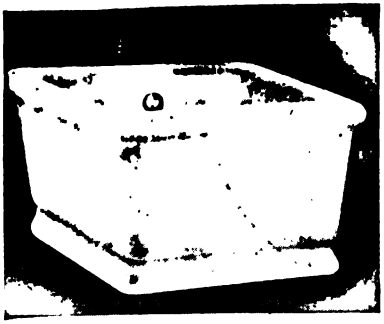


Fig. 23. Porcelain Foot Bath with Standard Fittings
Courtesy of Federal-Huber Company, Chicago

Fig. 24. Typical Baby Bath
Courtesy of Crane Company, Chicago

Foot Baths. An ordinary sitz bath can be used conveniently for a foot bath, but where there is no demand for such a bath,

a porcelain or porcelain enameled iron foot bath with integral base and 2½-inch roll rim, Fig. 23, can be installed. The approximate size of the foot bath, length over all, is 25 inches; width over rim, 21 inches; depth inside, 10 inches; and from floor to top of rim, 13 inches.

Baby Baths. Before leaving this branch of the work, it may be advisable to mention the "baby bath", Fig. 24. It is needless to say that only the wealthy can afford such a luxury, and there is no special demand for them. However, they are most convenient for the nurse as they fill and empty rapidly and are economical in the use of water.

WATER CLOSETS

Essential Features. The last few years have brought about some wonderful improvements in the style and construction of water closets. Comparing our present water closets with those of the pan and hopper types installed a few years ago, encased in woodwork and forming a chamber in which foul matter collected and developed, we find we have almost reached the acme of perfection. Nevertheless, all manufacturers of sanitary fixtures are constantly endeavoring to improve their product.

There are several points to be observed in selecting a suitable closet, which are as follows:

It must be constructed of a nonabsorbent and noncorrosive material.

It must have a small surface area, as this is always likely to become foul.

The basin should contain a large quantity of water.

It must have a good trap and a good depth of water seal.

The back should be as near vertical as practicable to obviate fouling.

It must be provided with a good flushing rim which will direct the water in such a manner that it will thoroughly cleanse the interior surface of the bowl and carry the excremental matter through the trap and into the soil pipe.

It must be constructed on the open or independent principle and fixed free from all casings or coverings.

Types of Water Closets. Types of water closets are innumerable and are separable into classes according to the principles of

action. Porcelain and painted or enameled iron are the materials used. Porcelain is more fragile, but has the better finish, and is susceptible of a greater variety of design and ornamentation. The all-vitreous body of water-closet china of today is far superior to the glazed clay ware of the past, which, depending only on surface impermeability, soon cracked badly, thus permitting absorption, the forerunner of odors which no plumber's skill could prevent. Enameled iron has not so durable a surface, but will stand rough usage, and has the advantage of very seldom cracking from frost even though the water in the trap freezes.

The greater relative advantage and durability of the porcelain closet over the best qualities of enameled-iron fixtures should not be overlooked. There is less adherence of the foul wastes to a porcelain surface than to the enameled surface. It is also a fact that enamel is subject more or less to abrasion by the use of harsh scouring materials, as well as to decomposition by uric acid and water-closet discharges, and is therefore not a very durable material. These statements can be confirmed by observation of closets which have been in use for a number of years.

Iron closets of the better forms are used most in public places, stores, warehouses, etc. The pan closet, of iron with earthenware bowl, is not now installed. For these, a trap was placed under the floor. The pan, operated by the same lever as the flushing valve, retained water, partially sealing the body from the bowl. The flush was by the swirling of a stream which entered tangentially under the rim. The bowls were round, as is necessary in all hopper closets thus washed, for water will not swirl in an oval bowl.

The objection to the pan water-closet is due principally to the fact that the outer bowl or container is a receptacle of filth which can never be cleansed properly. When the pan deposits its contents in the lower portion of the fixture, a considerable amount of the filth is spattered upon its inner walls and is not subject to the cleansing effect of the stream of water which scours only the upper bowl. When the closet is operated, the odors from this concealed surface permeate the room in an objectionable manner. The pneumatic form withdrew sewer air from between two traps and expelled it into the room through the bowl and was also expensive; it was therefore discarded. This objectionable feature

of construction is present in pneumatic range closets. The range, however, is rapidly losing favor and will shortly be discarded.

The pan and plunger forms of closets were seperseded because of their filthiness, although with them, flush and supply valves were brought to a high state of perfection; this is a benefit which the trade will always profit from by continued application of the principles, as is being done with time valves in various ways on direct flushing devices now in use and with ball cocks built on the principle of the old Jennings diaphragm valve.

A sectional view of the *combined hopper and trap pedestal* of today is shown in Fig. 25. It is made in one piece, in both porcelain and enameled iron. This form resulted from the separate hopper and trap fixtures before mentioned. The combined form has an oval bowl and integral flushing rim for tank supply.

The *wash-out* closet is a modification of the combined hopper and trap, being formed with a dipping bed under the mouth of the bowl, which retains enough water to keep soil from sticking to the surface. The water-bed makes it necessary to discharge the contents at either the front or rear of the bowl. The back-outlet wash-out is most repulsive to view; in them the drop-leg, which the flush never washes thoroughly, is always in view, so that its filthy condition suggests cleansing by hand. The front-outlet wash-out, shown in section in Fig. 26, is of more inviting appearance; but the drop-leg, although hidden, is there just the same. This type is rapidly becoming obsolete.

Both the wash-out and the combined hopper and trap types have one fault in common. The trap almost always contains the soil from one usage. When the contents of the trap are flushed out after using, sometimes a similar mass refills it. Of course, two or three consecutive flushes would leave comparatively clean water in the trap, but this is not to be expected in regular usage.

On certain occasions the wash-out may serve a useful purpose on account of the water-bed. The stools of children or the sick may thus be easily observed at the will of the physician or at the discretion of those in charge, while such is impossible where the soil is submerged at once.

Pneumatic siphon closets of various types have been put on the market. A good example of the type requiring two traps with an

air-space between, is shown in Fig. 27. A specially constructed flushing tank is connected with the air-space between the traps. The falling of the flush water creates a partial vacuum in the bottom compartment of the tank, which induces siphonage of the bowl contents.

In the effort to maintain a plenum in the flushing compartment of the tank while the flush water is flowing into the closet, the air between the traps is extracted, being drawn up through the air-pipe into the tank. Atmospheric pressure presses the water out of the bowl and upper trap when the pressure below it is sufficiently reduced. This water, added to the flushing water and that of the lower trap seal, which has been drawn above its normal level in response to the vacuum, is sufficient to form the long leg of an ordinary siphon; and thus both traps would be entirely emptied were it not for

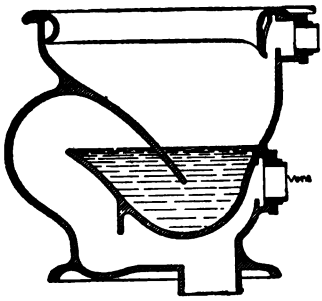


Fig. 26. Section of Combined Hopper and Trap Closet

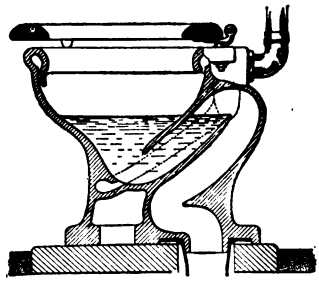


Fig. 25. Section of Front Outlet Wash-Out Closet

the vent in the crown of the lower trap breaking the siphonage in time to save a water seal for the lower trap.

The upper trap with water visible in the closet bowl in repose, is supplied by the *after-fill*, thus establishing conditions for the next action. The lower trap of such closets must be back-vented, and it is essential that the upper trap have no back vent.

The proper action of the tank is necessary to operate a pneumatic closet. A closet constructed on any other principle can be flushed with a bucket, by hand, if its tank is out of order. When a pneumatic closet gets contrary, pouring water into the bowl by hand simply fills or overflows it. The outlet is air-bound, and no passage of water to the soil pipe can take place until the barrier of air between the traps is removed.

The closets now accorded first place and generally used in the best work, are of the *Jet-Siphon* type, illustrated by the sectional view, Fig. 28. These use more water than is necessary to flush other kinds of closets, because a portion of the water is employed to produce the siphonage. A channel leading from the flush-water inlet to the bottom of the trap, conveys a stream of water to the trap leg, and injects it upward therein. The water in the channel has considerable velocity, and, being discharged into the water in the trap, imparts its energy to the whole mass, which, aided by the rise due to the incoming water from the flushing rim, moves upward at a proportionally slower but increasing speed depending on the ratio of mass and jet. When the water in the trap has been lifted in this way to an extent where sufficient of it can fall over the weir into the out-leg of the trap, a siphonic movement begins, and true siphonage finally takes place. Before the closet tank is emptied, siphonage sweeps out the trap thoroughly; and what water falls back into the bowl when the siphon breaks, together with the incoming jet and flush, often causes a second siphonage.

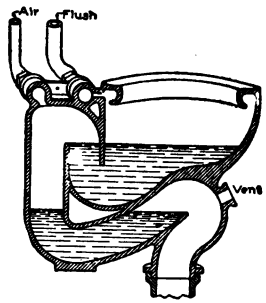


Fig. 27. Section of Pneumatic Siphon Closet, with Two Traps and Intervening Air-Space.

Accuracy in pointing the jet and in shaping the surfaces of its environment, are essential. If the surface above the jet-hole favors interference by the water flowing from the bowl, siphonage will be delayed and abortive, and may not take place at all. So, also, if the jet is not directed so as to maintain approximate concentricity in its travel through the mass of water, its energy is not expended to advantage, and failure is likely.

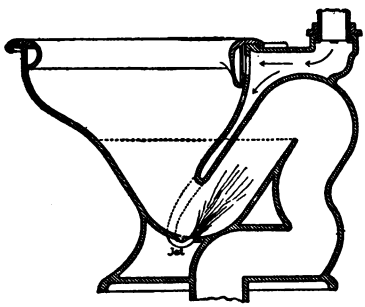


Fig. 28. Section of Jet-Siphon Closet.

There is no excuse for iron closets not siphoning perfectly. The iron pattern can be altered until it gives the best effect in practice, after which all closets cast from it should do the same. With porce-

into account sanitation laws already existing in many places and principles already known and established throughout the country governing the restrictions of fouling areas in sanitary apparatus.

Notwithstanding these logical contentions, frost-proof closets are now being used exten-

Fig. 31. Layout for Frost-Proof Closet with Galvanized-Iron Supply Tank

Fig. 32. Layout for Frost-Proof Closet without Supply Tank

Courtesy of Standard Sanitary Manufacturing Company, Pittsburgh, Pennsylvania

sively in outhouses and other exposed places. Although they cannot be considered the acme of sanitary perfection, owing to the large area exposed to fouling and the small area of water contained in the trap, no other form of closet will stand such locations

under like conditions and, being installed outside, adequate ventilation is always assured.

In the most approved types, the basins consist of an enameled cast-iron round hopper connected with a 4-inch cast-iron soil pipe which discharges into a trap about five feet below the level of the floor. The supply valve also is placed below the freezing depth and is operated by a pull or by seat action.

A typical frost-proof closet with galvanized-iron supply tank is shown in Fig. 31. The pressing down of the seat opens the supply valve and allows the water to flow into the tank. On rising from the seat, the supply valve closes and the water in the tank flushes the basin. After the flushing has taken place, the water remaining in the pipe above the valve drains off into the water-closet trap, through a small drain tube. When the fixture is not in use, there is no water standing in the flush tank or at any point in the piping above the supply valve. In Fig. 32 the flush tank is omitted, the closet being flushed direct from the supply pipe.

Closet Tanks. Closets are operated with pull or push-button tanks requiring the attention of the user and are also made of the seat-action type. Children are likely to be forgetful and visitors to public toilet rooms indifferent to such an extent that automatic closets are desirable for public places and schools.

Closets are fitted with two styles of tanks—one placed about 7 feet from the floor and serving with a flush pipe never more than $1\frac{1}{2}$ inches in diameter, and the other placed low down, as close to the bowl as connections will permit. Examples of the *high-tank* and *low-tank* arrangements are shown in Figs. 33 and 34, respectively. The low tanks are wider and deeper than the high style but do not extend out from the wall so much. The low position delivers the water at much less velocity than the elevated style and, to secure the utmost speed and the necessary volume, the flush connection is never less than 2 inches in a low-tank closet. The rim and jet channel are proportionately larger in bowls intended for use with low tanks. High tanks are about 17 by 9 by 10 inches. Sheet lead and sheet copper are used for closet tank linings. Some kinds of water, through galvanic action, attack the soldering of the seams in copper-lined tanks with more

effect than where lead alone is used. Generally, however, copper-lined tanks give satisfaction if the copper is heavy enough (12 to 16 oz.) and properly put in. Some makers lock-seam the linings water-tight, and solder on the outside before placing the copper in the wood case.

On account of the greater depth of low tanks, swelling of the wood case has, doubtless, been the cause of most of the trouble experienced with this type. When

Fig. 33. Modern High Tank Closet
Courtesy of Federal-Huber Company, Chicago

Fig. 34. Modern Low Tank Closet
Courtesy of The Trenton Potteries Company, Trenton, New Jersey

put together in the factory, the wood is very dry, and after being used for a short time, increases in height as a result of swelling from dampness. If the lining be tacked to the wood at bottom and top, injury is sure to result. Tacking at the top only is open to similar objections. It is now the practice to omit fastening the lining. Cast-iron tanks enameled two coats in and out give excellent service and so far have caused no trouble from sweating. Iron tanks with sheet metal interior lining have also proven satisfactory. Very great care has been found necessary with ball cocks for low tanks, in order to secure proper after-fill, the flush connection

being too short to aid much in resealing the bowl with its drainings. Low tanks flush with much less noise than high ones, and permit placing the closet under windows and low ceilings. Low ones require more width on account of the tank, and more depth from the wall to the front, as the seat and lid must be placed far enough forward to be thrown back and remain leaning against the front of the tank. Low tanks are provided with ventilated covers; while the high pattern which is out of children's reach, is left open at the top. The fewer working parts in a tank, the less likely it is to get out of order.

A type of seat-action after-wash closet very seldom placed in private houses, is that with closed metal tank, as represented in Fig. 35. Depressing the seat opens a valve in the supply, and the water passes up through a flush pipe into a closed tank. The air in the tank is compressed until the air-pressure counterbalances that of the water. When the seat is released, the supply valve closes and a valve is opened, establishing communication between the closet and the tank. The compressed air then expels the water in the tank, flushing the closet just as a large supply with corresponding pressure would do without a tank. Closed-tank closets depend on pressure. The space occupied by the air in the tank is inversely proportional to the pressure; hence, even in heavy pressure, considerable of the tank's capacity is yet occupied by air when equilibrium is established; and the less the pressure, the smaller the amount of water it is possible to get into the tank. They are therefore not fit for very light pressures, though they sometimes serve well in the basement of a building where failure would be certain on the upper floor.

Fig. 35. Siphon-Jet Closet with Seat-Operating Pressure Tank
Courtesy of Crane Company, Chicago

Condensation on single-shell sheet metal tanks is annoying. Open tanks of porcelain and iron are used more or less, but sweating is hard to overcome. Zinc paint and ground cork finishes have been employed with some satisfaction; and drip-cup collars discharging into the flush just under the tank on high-tank closets have served in this capacity, but nothing overcomes the sweating so well as a tight wood case. Insulated metal cases and double enameled cast tank, before mentioned, will prove the only serious rivals to the wood-case tank. Some makes of the pressure-tank closet require too much weight on the seat for successful operation by a child, and children would as a rule leave the seat too soon to allow the tank to fill reasonably well. The after-fill is accomplished by projecting the flush connection into the tank an inch or more, and drilling a hole $\frac{1}{4}$ inch or less in diameter through it near the bottom of tank. The rapid flow ceases when the water-level falls to the upper end of the inward-projecting flush connection, and the after-fill drains into the flush.

The flush fittings of an open tank consist essentially of a valve to admit water to the flush pipe; an overflow always open to the flush pipe; and a lever and connection, with chain and pull or button, to open the flush valve. A simple example of these is the siphon gooseneck, with flush-valve disc on one end and lever connection at the other. Prongs extend below the disc to guide and keep it in place. The overflow is through the gooseneck. Lifting the gooseneck an instant permits enough water to flow down the flush to start the siphon through it when the pull is released. The tank then siphons to the lower end of the gooseneck arm.

Where shortness of flush pipe or form of closet requires a decided after-fill, this is secured by special provision in the flush fittings, or by leading some of the supply delivered by the ball cock into the overflow.

The supply fittings of a closet tank consist merely of a ball cock of suitable form. For light pressure, simple leverage suffices. For heavy pressure, the inlet in the valve would have to be too small, or the ball too large and stem too long, for a small tank, if simple leverage were employed. Therefore compound-leverage cocks are usually substituted where the pressure contended with is over 30 pounds. There are ball cocks made in which the buoyancy of the ball merely operates a small secondary valve in a way to establish the initial

pressure over a disc of larger upper surface than that of the under side which covers the main water inlet of the cock. The disc is thus seated by the differential principle regardless of the pressure; and a 4-inch ball will close almost any size valve against any pressure.

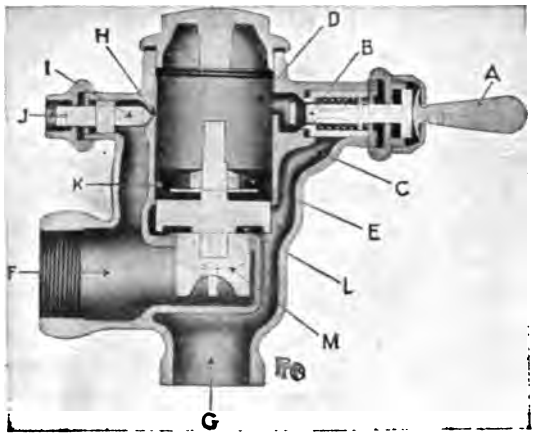
When the cock is attached through the bottom of the tank, no precaution against sound is necessary. When the cock is fitted in high up, a pipe from the delivery is extended to near the bottom of tank for the purpose of muffling the sound of the water as it fills the tank. An unmuffled delivery and a high-tank flush make considerable noise when the closet is flushed and are suggestive and very embarrassing to sensitive people. Silent action is therefore the goal for which many strive. Silence at the expense of thoroughly washing the closet surfaces and flushing out the contents, is not desirable; some noise is necessary to the rapidity of action essential to thorough scouring and evacuation.

Tanks requiring the flush valve to be held off the seat during the entire flush are now no longer installed. Perfect silence in the flush pipe of a high-tank closet has been obtained by a type of flush fitting that permits the pipe to hang full of water. The flush valve being opened, water begins to flow into the closet immediately. When the valve closes, no air having access at the upper end of the flush, the pipe remains filled. The flush valve of such a closet must close absolutely water-tight to prevent continual dribbling into the bowl.

Flushometers. Of late years, direct flushing valves or flushometers of many forms have been a feature of water-closet design. These valves make individual closet tanks unnecessary.

A section of a good type of flushometer is shown in Fig. 36A, in which the letters *A* to *M* represent the following: *A*—oscillating handle; *B*—release stem; *C*—by-pass; *D*—cylinder; *E*—piston; F—waterway to valve; *G*—waterway to closet; *H*—regulating by-pass; *I*—regulating screw; *J*—loose key; *K*—specially treated leather washer; *L*—encased leather seat washer; and *M*—refill disc.

The Boyle valve is of the balanced plunger type, that is, the piston is balanced so that the pressure of the water on the top will overcome the pressure at the bottom and close the valve. When the pressure at the top is removed, the pressure at the bottom



A

B

Fig. 36. Direct-Flushing Closet—Flushing Valve Shown in Section Above
Courtesy of Federal-Huber Company, Chicago

will raise the piston and open the valve. The piston is fitted with a specially treated leather washer which prevents the cylinder from being harmed by sand or other foreign matter. This washer can be replaced when necessary by removing the valve cap and lifting out the piston. It has only three moving parts: the handle, the release stem, and the piston.

Action. The action is as follows: When the oscillating handle *A* is pushed, it moves the release stem *B*, which allows the water in the cylinder *D* to run out through the by-pass *C*. This releases the pressure of the water on the top of the piston *E* and allows the water from the supply *F* to force it up and to run into the closet through the outlet *G*. While the water is running to the closet, a portion goes up the regulating by-pass *H* into the cylinder *D* where its pressure forces the piston *E* to close. The faster the water enters the cylinder *D* through the regulating by-pass *H* the quicker the valve will close, and *vice versa*. The length of the flush is controlled by the regulating screw *I* which is adjusted by a loose key at *J*. This permits the valve to be regulated from the outside without disturbing the interior. The supply to the valve should be as straight and with as few bends as possible. It should never be less than $1\frac{1}{4}$-inch iron pipe size and should be increased as conditions demand. The pressure of the water at the valve should be maintained at not less than 20 pounds per square inch. When a large number of water closets are installed in one building, it is best to supply the flushometers from a large tank installed for this purpose. From the tank, a proper size flush main is run direct to the closets, independent of the water supply or other fixtures. One tank with large flushing main will serve all the closets, and thus the individual tanks and equipment are not needed. Furthermore, no trouble is then experienced in providing suitable space for the small tanks. The valves may, if desired, be placed out of sight, and only the operating lever brought to view in a convenient position.

Range Closets. Batteries of individual closets are usual in office buildings and many other such structures; but in schools and in many public places open to all classes, ranges divided into stalls or compartments have been considered a satisfactory solution of the problem.

The objections to the range type of fixture are inherent in the design. The fouling surface of a trough fixture is much greater than that of the number of individual closets to which the fixture corresponds, and certain parts of this surface are not subject to an adequate flushing action. A certain portion of the surface, much larger relatively than that in individual fixtures, is exposed to spattering with the filth, and is alternately wet and dry. It is also true that the method of applying the water for scouring purposes is much less satisfactory than with single closets. A further objection to the range fixture is that in general its material is less desirable for the purpose than the earthenware or porcelain used for closets. On account of these deficiencies, for some ten years past, individual closets have been used in public schools in certain cities which have given the most attention to this branch of sanitation, and their use is being extended.

Range closets have automatic flushing tanks acting at any required interval between flushes. The tanks are, as a rule, without moving parts, and give good service without much attention after the supply is once set to flush at the interval desired. Whether the users of a closet are indifferent or irresponsible, does not change the result of abuse; and the range type of closet overcomes many annoyances attending the use of ordinary individual closets in unsuitable places—institutions for the insane and feeble-minded, for example. Ranges, like seat-action closets, are not dependent on the user, who may forget to pull a chain or push a button and thereby leave the closet foul.

Various forms of ranges are now operated on the siphon eduction principle. Siphonic eduction is accomplished in three ways—first, by the double trap and air-pipe to the tank indicated by the sectional view, Fig. 37, and operating exactly like the individual pneumatic closet already described; second, by a siphon outlet-end in which the water falls over a central weir that maintains the proper depth of water until the flush begins, and causes siphonage by breaking up and filling the channel as it passes through a constricted bend below. The latter method is shown in section in Fig. 38. Still another type of range is made to siphon by jet-action, just as the individual jet-siphon closet does, the trap providing a retaining weir which holds the water at the proper level in the range between flushes.

There are wash-out ranges with sloping weirs at the outlet to retain enough water to keep soil from sticking. These are open troughs, and the plumber provides the trap. Some siphon ranges are of the open-trough pattern, but the trap or the siphon outlet is a part of the fixture. All open-trough ranges can be supplied with a ventilating section from which a large vent pipe may be carried to a stack in which a draft is insured by a hot flue or some other means. Such ventilation changes the air in the room; and by having lids to all the seats, odors from the entire trough may be uniformly removed by

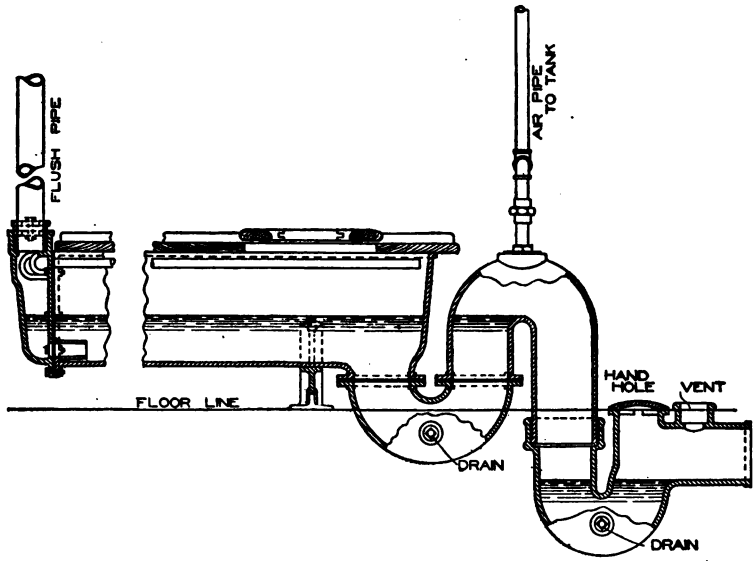


Fig. 37. Section of Range Closet, with Double Trap and with Air-Pipe to Tank to Cause Siphonic Eduction.

leaving up one lid only, at the end opposite the vent pipe. Some forms, having individual flushing-rim bowls cast integral with the section, are supplied by one general flush pipe, as indicated by the plan and elevation shown in Fig. 39. In these, each bowl is separately water-sealed, as the normal water-level is above the general conduit into which the bowls discharge.

Other forms, which receive the entire flush at one end, are water-sealed between the seat holes. The seat-openings, instead of converging like flushing-rim bowls, diverge downward, so that, as the water-level recedes in the sections during flushing, soil falls away from the surface by gravity instead of grinding against it. Therefore, so far

as cleanliness is concerned, the type with diverging surfaces but without the scouring effect of flowing water in the openings is, in operation, the practical equivalent of the flushing-rim type with converging surfaces. The open-trough ranges, including the jet-siphon type, have perforated wash-down pipes along the sides and ends, which, however, have little value. The open troughs are made in cast sections as long as convenient, joined by flanges with rubber gaskets and bolts. Suitable feet or chairs for supports are furnished with these fixtures.

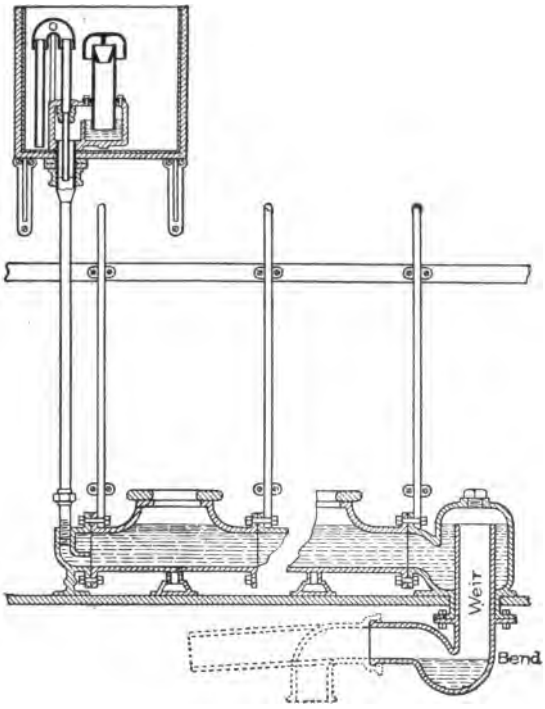


Fig. 38. Section of Range Closet, with Siphon-Outlet End.

Cast partitions, partitions and backs, and full compartment partitions, with slat doors and indicators, are furnished to order in any style or combination desired. For example, the range for a schoolroom may consist altogether of 24-inch sections or divisions, except one intended for the teachers' use made 30 inches and fitted with door and full-length partitions to give a thoroughly private compartment. Ranges are usually made of cast iron, and almost invariably finished with enameled interior and painted exterior. Bowl or section ventilation is provided for where possible. Wood seats and covers are generally used; but enameled-iron top frames with hinged seats and covers, and rigid enameled seats, are also made.

The lower trap of a double-trap range must be ventilated. All soil-pipe stacks into which ranges discharge, and fixtures connected

to them, must be well protected against siphonage, because the volume of water discharged at one time by a range is sufficient to siphon traps that ordinarily would retain their seals.

Urinals. Sectional urinals are made of the same materials and finish, and with much the same types of design, as range closets. They are generally installed in the same classes of buildings as range closets; but such urinals will often be found in the same toilet-room with individual closets. Roll-rim enameled troughs, with back and with simple perforated wash-down flush pipes on the back, are available. Solid porcelain stalls, are also in the market.

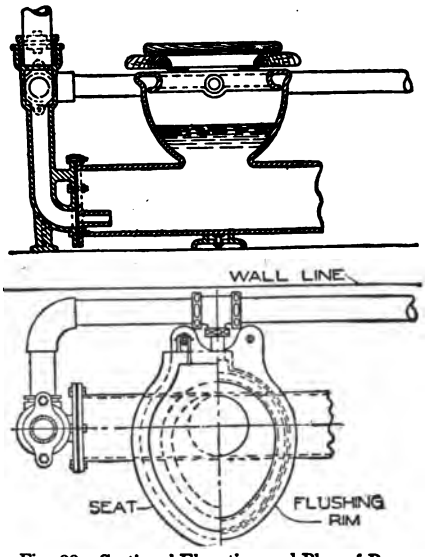


Fig. 39. Sectional Elevation and Plan of Range Closet Seat with Flushing-Rim Bowl Supplied from General Flush-Pipe

Single urinals are usually of porcelain, although some have been made of iron. Pedestal flushing rim urinals, resembling an extra

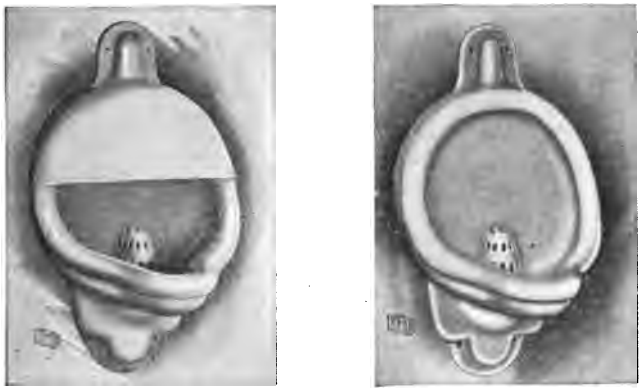


Fig. 40. Standard Types of Vitreous China Urinals
Courtesy of Federal-Huber Company, Chicago

tall water-closet bowl, are now regular market fixtures. The common types are plain or lipped, Fig. 40, made in flat-back and corner

designs. Direct-flushing valves of the same type as used on closets, adapted to the purpose, and cocks of various types, are the means of flushing generally provided for a single urinal. When two or more are placed in one toilet-room, an automatic tank with branched flush pipe is employed. These tanks are of greater variety than those used with range closets. The tilting bucket, pivoted within a tank case, which empties itself periodically by means of the flow of water changing the center of gravity to the unsupported side and tipping it just before it overflows, is a familiar type of automatic urinal-flushing tank. The standard tank with immovable parts, which siphons automatically, is the most prevalent. A section showing the "Watrous" automatic tank valve is given in Fig. 41.

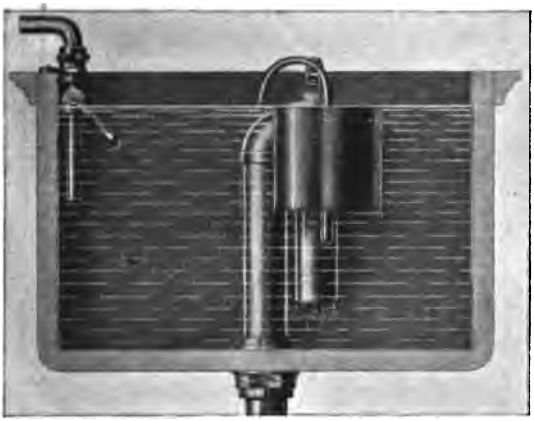


Fig. 41. "Watrous" Automatic Tank Valve
Courtesy of Federal-Huber Company, Chicago

Another design consists of a tank with common siphon, fitted with a ball cock which *opens*, instead of closing, as the water in the tank lifts the ball. The interval between flushes is governed by a small bibb cock. When water lifts the ball, the ball cock also admits water, the tank filling

Fig. 42. Urinal Stalls of Slate, Flushed by Perforated Pipe, with Guttered Floor
Courtesy of Federal-Huber Company, Chicago

rapidly. The higher the ball is lifted, the faster the tank fills, so that by the time the water-level reaches a point where water begins to flow over the neck of the siphon, it is coming into the tank rapidly enough to more than keep pace with the overflow necessary to start the siphon. True siphonage, however, empties the tank much faster than the supply can fill it; and the tank is soon empty, leaving the small bibb cock to admit water again slowly to where this action can be repeated.

Individual urinals which siphon by admitting additional water to that which normally stands in the fixture, and various other types, will be best understood from a study of dealers' catalogues. In good work, marble backs and partitions usually enclose the urinals on three sides. Marble and slate stalls of various construction, with channeled and guttered floor, as shown in Fig. 42, all washed by perforated pipes fixed along the surfaces, are frequently used in lieu of specific urinal fixtures. A thick base of slab material is sometimes used, the gutter and drain-hole being cut in it. Cast-iron gutters, galvanized or enameled, with an outlet-end adapted to a soil-pipe connection are supplied by the makers.

MISCELLANEOUS FIXTURES

Drinking Fountains. Drinking fountains are now frequently used in stores, schools, and residences, the various fixtures adapted to such installations being readily obtainable. The basins or drip-slabs for public indoor fountains, are often cut to order by the manufacturer; and the cooling and faucet arrangements are provided by the plumber. Porcelain, enameled-iron, and marble fountains of stock designs are made. Most municipal regulations for schools require rough-like basins to be provided with sanitary drinking cups, Fig. 43, to prevent infection. The fixture shown in Fig. 44, consisting of solid porcelain, in which the drain-slab and the high back consitute a single piece, is of recent design, presents an excellent appearance, and has the advantage of being easily kept in immaculate condition. The two fountain drinking cups are built low to give a plentiful flow without spattering, and the compression cocks below are easy of manipulation.

One device, which serves well for common use, is the ordinary lavatory provided with a stiff perforated bottom fitting extending

well up toward the top of the bowl. This, with a proper faucet on the slab and a cup-chain fitted to the extra faucet-hole, makes a useful but not attractive fixture.

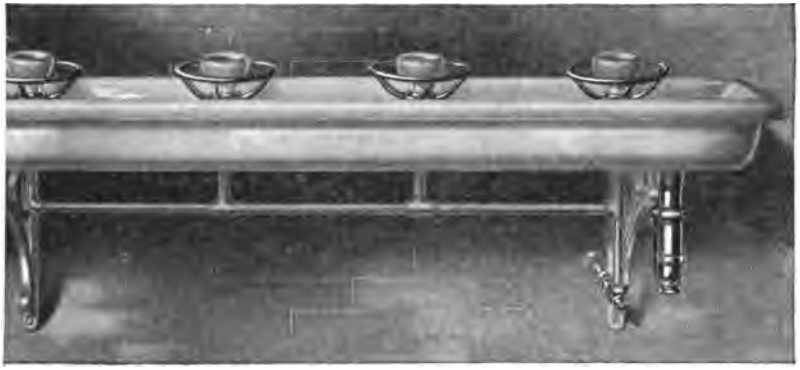


Fig. 43. Enameled-Iron Fountain Receptor with Self-Closing Heads Particularly Designed for Schools and Other Public Places
Courtesy of Crane Company, Chicago

Recessed porcelain and enameled fountains designed to be placed in wall niches and having concealed connections, as suggested by Fig. 45, are neat and require very little room outside the finished wall line. Countersunk slabs with strainer waste, with back either integral or separate as design or material dictates, are made in marble and porcelain. Marble fountains are adaptable to any location, because the slab and back can be cut to any shape or dimensions preferred. The fountain proper, faucet, cup, and waste-pipe connection with strainer, are all that is supplied by the makers.

Fig. 44. Double Vitreous China-Fountain with Integral Back and Separate Back Shield
Courtesy of Federal-Huber Company, Chicago

A type of fountain shown in Fig. 46, is provided with a flowing jet of water from which one can drink without placing the lips in contact with any metal surface. The small central bowl or cup is constantly sub-

merged and cleansed in the stream of water which passes outwardly over it, thus avoiding the danger incident to the common use of the same drinking cup by many persons. The surface does not afford lodgement to possible germs of disease which are most liable to transmit contagion when allowed to become dry and adhere to a surface. In fact, city ordinances require that all public drinking fountains be of the sanitary type.

Yard Fountains. Plumbers are rarely called upon to design the basin or attend to building the retaining walls of yard fountains or those built in parks and other public places, but they must be prepared to supply them with water and drain off the waste.

The basins are invariably circular. A conical bench is usually left in the center of the basin with sloping sides. The size of the bench or mound through which the supply rises is made to suit the fountain fixture. All sediment collects on the ring of low surface surrounding the bench and the waste pipe is brought through the bottom at the lowest point. The overflow enters at the bottom, but it may be entered higher up and on the waste pipe side if desired. The center is undoubtedly the best position for it, as the current to the overflow causes more sediment to collect on the overflow side and there is thus less chance of the drain being banked over when needed. The overflow should be protected by a netting to keep leaves and other rubbish out of the waste pipe. The drain should extend about two inches above the bottom so that a reasonable deposit of sediment will not interfere with its prompt action. A beehive strainer or netting should cover the outlet.

Suitable fountain fixtures may be found in catalogues. Such fixtures are numberless and range in price from a few dollars to almost any figure.

Lavatories. Lavatories are made from porcelain, enameled iron, marble, and onyx, in numerous patterns. The number of designs is so large that they are best understood if considered in the classes into which they may be divided. In marble and onyx fixtures, the slab, back, and bowl are necessarily separate pieces. In any but very accurate fitting and erecting, the unavoidable joints soon invite the accumulation of dirt, soapsuds, and other foul matter. Poor workmanship, settling, abortive countersinks, and faucet bosses not cut free within the countersink, have in many cases

brought slab types of basins into unjust repute, or, at least, have given basis for strong talking points against them, which have been effectively so used. If made and installed in the most approved manner, these styles, properly cared for, offer little

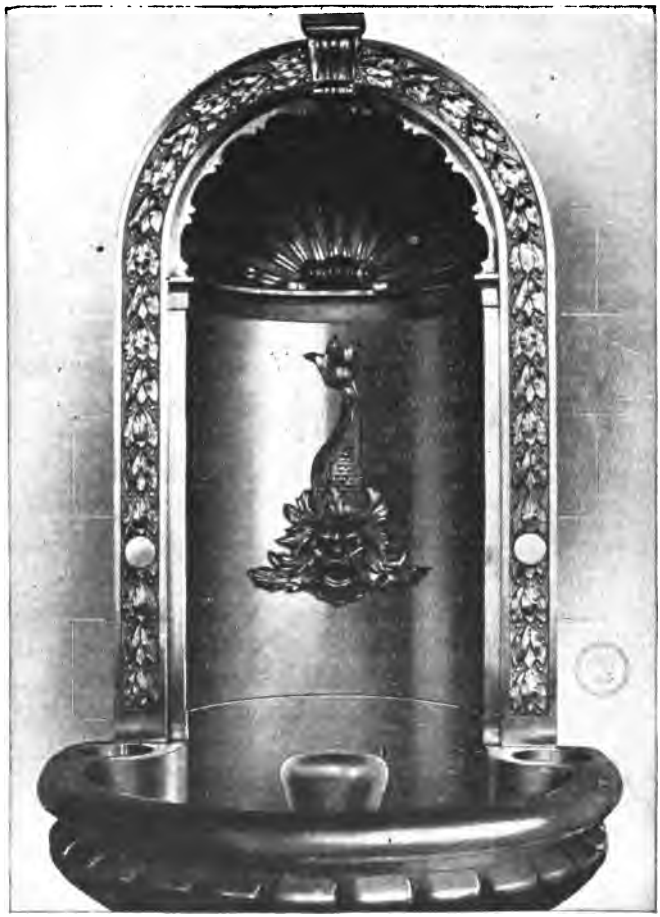


Fig. 45. Cast Bronze Recessed Drinking Fountain
Courtesy of Crane Company, Chicago

reason for severe criticism. One fact, however, must be borne in mind when comparing marble with other materials used for plumbing fixtures—namely, that marble is *not an impermeable stone.* Nearly all marbles (excepting only the very hardest and most dense) are quite absorbent, and depend upon the surface finish given to the

slab to resist the entrance of liquids into the body of the stone. As soon as the surface becomes roughened by wear, the greasy and acid wastes penetrate into the pores, and the marble becomes permanently discolored. Only a limited observation of the bad condition of marble floors or urinal slabs which have been subjected to use for a few years, is necessary to confirm this statement.

Ordinary Tennessee, Veined Italian, Hawkins County Tennessee, and Statuary Italian marble, range in cost in the order mentioned. Fancy imported marbles and onyx are much more expensive. Tennessee marble varies in color from grayish brown to very dark reddish brown, uniformly intermixed with light specks. The Hawkins County marble is bright reddish and white-mottled. All the ordinary materials are cut in stock sizes, and may also be had to order, like the more costly, in any size and shape desired. The type with apron or skirting, has legs, and the slab is supported by the skirting. When supported by brackets or leg-brackets, the strength of the slab is alone usually depended upon for support between the bearings. If brackets are properly spaced (as far from the ends as fittings will permit will never be too close together for any ordinary size), the weight is so balanced as to leave very little sagging strain on the slab.

Fig. 46. Enameled-Iron Fountain
Courtesy of Federal-Huber Company, Chicago

Built-in lavatories similar to Fig. 47 are often used and with appropriate fittings are very effective.

Porcelain and enameled-iron lavatories have bowl, back apron, and soap-cup in one piece. The pedestal of the lavatory illustrated in Fig. 48 is separate, of course, and no back is required, but the general features of integral construction are shown. The only injury possible to them is the marring or fracture of the glaze or enamel. Porcelain and iron lavatories, which can be furnished at reasonable cost, unlike those of marble, are adapted to pedestal support; and some very desirable patterns are therefore made in these materials only. Neither pedestal nor wall lavatories without backs, are suitable, except where the wall or wainscoting is of marble, tile, or other waterproof material.

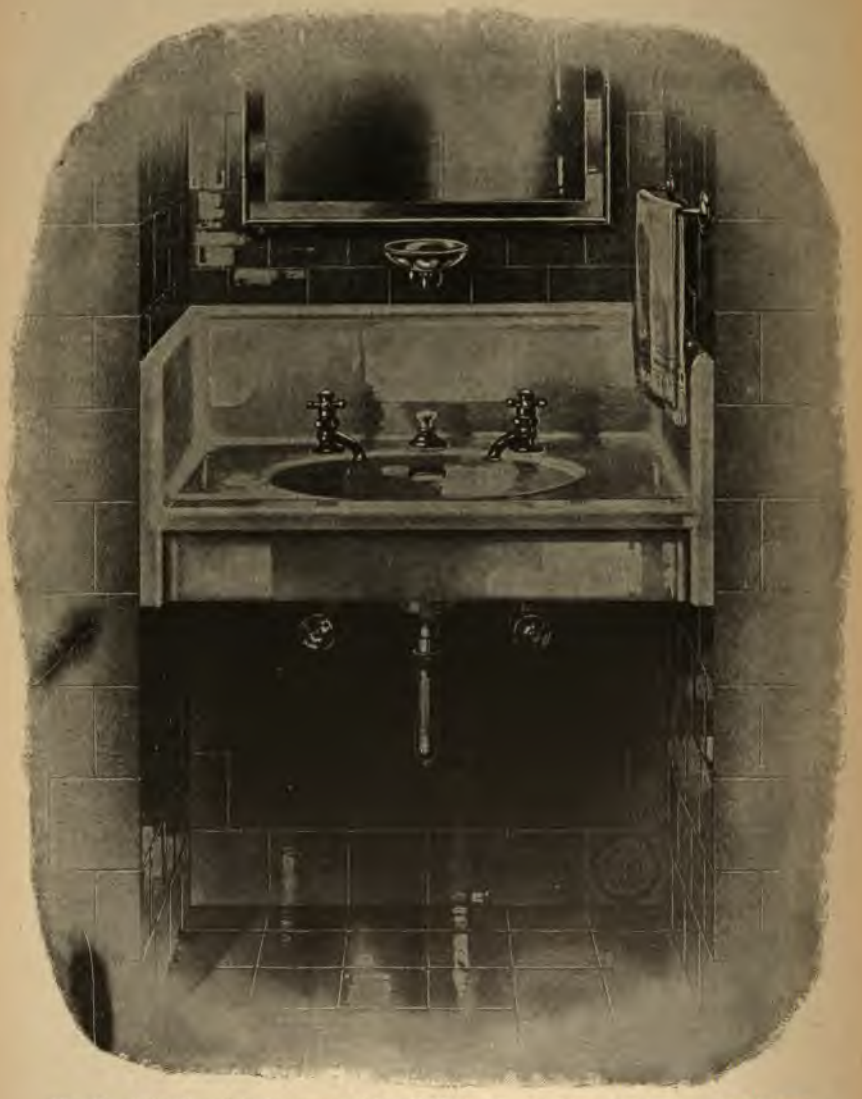


Fig. 47. Solid Porcelain Lavatory with Self-Closing Basin Faucets and Direct Lift Waste
Courtesy of Crane Company, Chicago

To provide for leaving the floor clear and free of obstruction, lavatories supported on brackets or hangers, as indicated in Fig. 49, with supply, waste, and ventilating pipes fitted on or into the wall, are best. If found practicable, a neater job results if all pipes leading to and from pedestal lavatories are carried through the pedestal. A supply and waste run to the floor is generally far easier and cheaper to secure than the fitting of all pipes to the wall.

The purchaser seeking iron or porcelain fixtures, has no choice of styles beyond that which the market regularly affords. If he prefers the workable materials, he should insist upon certain features of design which are essential to the best service. Abrupt edges and sharp corners should be avoided; the slab ought to be at least 1½ inches thick, and the back not less than 12 inches high; the general dimensions must be as liberal as space will allow or the service demands (not less than 22 by 32 inches for a 14 by 17-inch bowl); the countersinking must be deep, $\frac{3}{16}$ to $\frac{1}{4}$ inch; the faucet bosses must not join the general border level at all; the faucets must not be less than 12 inches apart, nor so near the bowl that it will be difficult to secure them to the slab; nor may they be placed so close to the back as to make repairing troublesome with any type of Fuller faucets; the joint surface of the bowl must be ground to fit the slab, and provided with not less than four well-drilled anchor-holes for clamps to secure it.

Fig. 48. Lavatory on Pedestal
Courtesy of Federal-Huber Company, Chicago

Round bowls were formerly quite generally in use, but are now almost relegated to memory. The width of slab needed for a roomy, round bowl is too great; and at best the arms of the user must be cramped in a somewhat vertical and awkward position, while the smaller sizes are very uncomfortable in this respect. The sudden opening of the faucet when the bowl is empty, is likely to ricochet water with annoying results. This is caused by the water striking the curved bowl at a tangent; the action is not peculiar to the circular bowl; the oval or crescent, or, indeed, any shape of bowl that presents

a curved surface to which the faucet stream is tangent, favors the same result; the ovals in integral fixtures are the most annoying. Marble and onyx have an advantage over porcelain and enameled lavatories so far as ricocheting is concerned. The opening in the slab is not so large as the bowl, and thus a horizontal overhanging ledge is formed all around, above the bowl, which generally intercepts the water in a way to keep it off the floor and person. Porcelain and enameled fixtures have not this virtue. The bowl surface, being integral with the slab, is uninterrupted and continuous; hence ricocheting is more violent with them than is possible with the separate bowl.

Fig. 49. Vitreous China Lavatory with Integral Back
Courtesy of Trenton Potteries Company, Trenton, New Jersey

Oval bowls are now in general use on all types of lavatories. They employ slab space to the best advantage, and are the most convenient for use. The crescent or kidney shape, illustrated in Fig. 50, is, however, as far superior to the simple oval bowl as the oval is to the round. It permits the forearms to lie in a natural and most convenient position when dipping water to lave the face. This form of bowl should be accompanied with a scalloped or recessed front. The D-shaped bowl, and other bowls embracing the prime feature of the D-shape, while not so graceful in appearance, are, without exception, to be preferred, on the score of utter absence of ricocheting when the faucets are properly placed. The D-shape, a transverse section of which is shown in Fig. 51, has a semi-oval front, with the end lines continued parallel some distance past the major axis, and with a straight-line back nearly vertical. This form gives a nearly flat surface in the bottom between the back wall and major axis, on

which surface the stream strikes and breaks when the bowl is empty. A depth of water is quickly formed under the stream, which checks any spraying or spattering.

The traps used for lavatories are lead or brass (either cast or tubes), or combinations of these materials, plain or vented or of anti-siphon design. One trouble with lavatory trap ventilation, is the difficulty of obtaining a vertical rise directly above the trap. These vent connections should be carried as nearly vertical as possible, as high at least as the bottom of the lavatory slab, before any horizontal run is made; otherwise the choking of the waste pipe would float solid matters into places from which gravity would not dislodge them. In the absence of water-wash in the vent pipe, these solids would obstruct the vent and defeat its purpose. This danger is not given due attention by many plumbers. The patent and horn overflow bowls, with plug and chain, are the cheapest effective means of controlling the overflow and waste from the bowl. The standing waste, of essentially the same design as the waste fitting for a bathtub, with the body fitting projecting through the slab at the rear of the bowl, is perhaps the most satisfactory waste and overflow arrangement. Various schemes for operating basin stoppers by means of levers and swivels, are employed; but none of them has come into more than limited use.

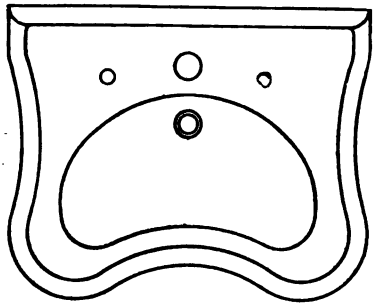


Fig. 50. Plan of Lavatory Slab with Crescent or Kidney-Shaped Bowl.

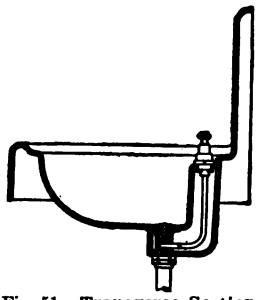


Fig. 51. Transverse Section of D-Shaped Lavatory Bowl.

Basin faucets, aside from special designs, are made on three general operating principles—(1) screw-compression; (2) eccentric action without springs; and (3) self-closing. They are also made in two types—with regular and low-down nozzles. All of these are represented in Fig. 52. The regular type has the nozzle some distance above the base flange, and screws into, or is cast on, the body. The low-down type has its nozzle with a flat bottom, hugging the slab as

closely as practicable. The objection to the low-down is the inaccessible narrow space between the nozzle and slab, which becomes filthy and is difficult to clean. High, projecting nozzles obstruct the space over the bowl, especially when washing the hair, but are otherwise most satisfactory. The high nozzle gives trouble with patterns of faucets that separate in the body for repairs, such as the Fuller type, which closes rapidly with pressure. The fault, however, is often that the slab is so shallow as to necessitate the faucets being placed too close to the back to turn without removing the nozzles. If these are cast on, removal of the whole faucet is required before it can be separated. Some faucets are made with union joint in the body, thus avoiding such trouble; but these are not widely used.

The false economy which often dictates the purchase of a small slab, generally also prevails in the selection of its trimmings. Compression faucets close against the pressure, and are slow in action, causing practically no reaction. They are generally responsible for the omission of air-chambers on supplies of medium pressure. On account of their slow action, they are suitable for high pressures although but little weight is given this fact by the trade. The features essential to good, lasting service in the compression faucet, are: a cross-handle, a stuffing box, a raised seat, and a swivel disc. Self-closing faucets of various patterns are made with a view to preventing waste of water, the intention being to compel the user to hold the faucet open only as long as water is needed, and to insure automatic closing when it is released. There are none such except the crown-handled, that an ingenious person cannot find means to hold open at will; yet, withal, self-closing faucets are of great value in reducing wastage. A rabbit-eared faucet can be kept open by placing a ring over the handles while squeezed together; the telegraph bibb, by weighting down or tying up the lever; and the T-handled, while not so easily controlled, can be tied open by a lever secured to the handle. The crown-handled design can be operated with ease by the hand of the user, but does not readily lend itself to unauthorized control by means of a mechanical stop. Self-closing faucets require strong and well-designed springs to close them against the force of the water. They have sometimes come into disrepute through leakage for lack of adequacy in this feature of their construction.

Lavatory supports should have positive means of leveling the slab, such as set screws, screw-dowels, or whatever adjustment the kind of lavatory and support may be best suited to. Lavatory brackets are generally at fault in having limited bearing at the bottom of the wall-face. This point of the bracket is where all the strain is thrown against the wall, and the effect is noticeable if the upper end springs away ever so little. Full-length brackets are not open to this criticism, but they interfere with the washboard or other finish next the floor.

Sinks. These are made in four general classes according to the purpose to be served—namely, Kitchen, Pantry, Slop, and Factory or Wash-Sinks. The materials used are:—Porcelain; enameled,

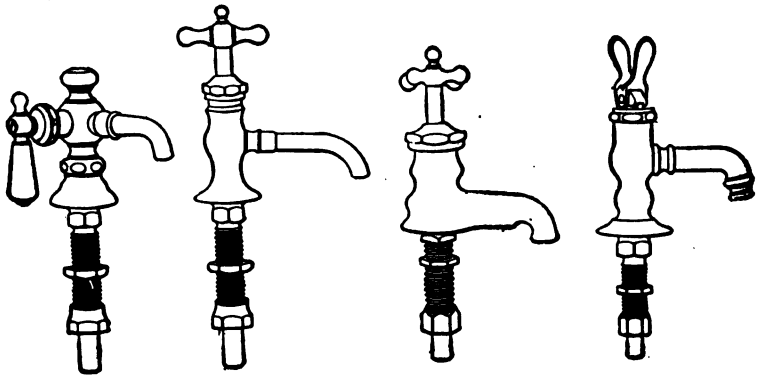


Fig. 52. Common Types of Basin Faucets

galvanized, and painted cast iron; enameled, galvanized, and painted wrought iron; brown glazed ware; copper; slate; soapstone; various compositions; and occasionally wood. Porcelain and enameled cast iron are most used, galvanized and painted sinks being confined principally to factory use. Sinks of extreme length, in one piece, or sectional, 6 to 8 inches deep, as shown in Fig. 53, with supply and faucets over the center line or at the side, belong to the factory class. There are roll-rim patterns, with bracket support and iron back, and with faucets fitted through the back. These are generally 8 inches deep and about 20 inches wide. The installation shown in Fig. 53 is particularly good on account of the skeleton character as it will collect little dirt.

Kitchen sinks vary in size according to general requirements. Common sizes are 18 by 30 inches and 20 by 30 inches. The depth

ranges from 6 to 7 inches. There are two types of iron sink—flat rim, with outlet at end; and roll-rim, with outlet in center. Neither style of outlet is always desirable as to connection; but the center outlet drains more directly. The flat-rim is not provided with legs. Cast legs were formerly furnished, being attached to the sink by slipping into dovetails. When legs are desired for this type, the plumber provides gas-pipe legs, with or without a top frame. Iron splash-backs are provided for flat-rim sinks, but not of the deep pattern in which air-chambers may be placed. Plumbers drill these sink rims to attach brackets or legs. and sometimes also to secure to them hardwood capping or drainboard. Hardwood drainboards are generally provided by the plumber's carpenter. Hardwood splash-backs, set free of the wall to permit circulation of air behind the fixture, are also provided. Sometimes marble splash-backs are provided. Marble is best, but is not in keeping with a flat-rim sink. The back may extend to the end of the drainboard, as represented in Fig. 54, or merely cover the length of the sink. Omitting the back behind the drainboard, is not often done. The drainboard should be free of the wall when the back is not extended. Iron sinks, with roll rim on front and ends, are furnished with drainboards suited to attach to either or both ends. These may be added as an after-consideration, or changed from side to side at will, if there is but one drainboard, or removed entirely, without marring the looks or service of the sink. This interchangeability commends itself to both plumber and customer.

Fig. 53. Individual Factory Lavatories
Courtesy of The Trenton Potteries Company

Roll-rim sinks, with the end recessed to receive a drainboard, are also made, but in any subsequent change of location require setting in the original position, so far as the drain is concerned.

Open strainers are most frequently fitted to sinks, in which case the sink cannot be then used for washing dishes, but merely serves as a support for dishpans and other vessels and as a catch-all for drippings from the drainer. Hence the open-strainer sink must be large enough to accommodate suitable washpans, etc., while one fitted with a plug-strainer should be relatively small if it is designed to use the sink proper as a washpan. A new form of sink waste connection is now a feature of the better class of enameled sinks, in which the connection is made by means of a spud and coupling something like

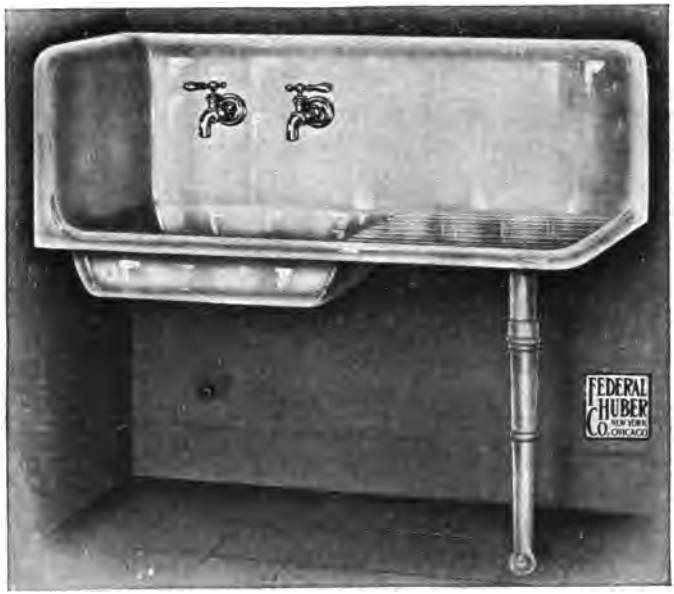


Fig. 54. Roll Rim Enameled-Iron Kitchen Sink Supported on Brackets. Splash-Back Omitted behind Drainboard

the ordinary lavatory coupling. In it the strainer is held down in a way less likely to cause injury to the sink lining at the waste hole.

The use of wooden sinks in large installations, such as hotel kitchens and restaurants, is not unusual, the theory of their use being that less breakage of crockery occurs, by reason of the softness of the material. However, because of the objection to any porous material which retains moisture and is subject to decomposition, wood is never suitable for this use, though with copper-lining it is permissible.

Rubber mats are essential for both sinks and drainboards having

enameled or glazed surfaces, in order to avoid accidental injury to both the fixture and the articles cleansed. As a matter of fact, the average dwelling has but one sink, which serves both kitchen and pantry purposes. Dual service is not always satisfactory, however, as no sink can be well adapted to both uses for a large family.

Porcelain and iron sinks have generally been supplied with loose backs; but sinks of one piece—that is, with sink and back integral—are now obtainable. Sinks with integral apron or skirting all around, placed free of the wall, are suitable where the wall is waterproof.

Sinks are built from slabs of natural stone as desired, and may be with or without drainboard or skirting. They are generally provided with a high splash-back. These sinks are not limited to the patterns of a moulding room, and easily keep pace with the desires of the purchasers. Selection is confined to a choice of material.

In the use of any natural stone, such as slate or soapstone, for plumbing fixtures, and especially for sinks, it should not be forgotten that angles and rectangular corners are with difficulty maintained entirely free from deposit. Although the flat surface can be readily scoured, it is always difficult to clean the sharp angles and corners satisfactorily. The difficulty is increased by the fact that some plastic jointing material, such as putty or cement, must be used in putting together the fixture; small fragments of this material project into the angles and render the corners rough.

Air-chambers may be cast in iron sink-backs, or independent cast or pipe chambers fitted in the cavity. The ordinary sink-back is not well suited to the convenience of the plumber where supplies to any fixtures pass up behind the sink. The faucet-holes cannot be changed, and slots for pipe are not provided at the top edge. Sawing these gaps after the goods are enameled, leaves the fixture with an unfinished appearance. The proportion of shank to the handle of faucets of the Fuller pattern used on sink-backs, must be such that the handles will turn straight back.

A popular fixture of comparatively late design, adapted for small dwellings and now made in the cheaper materials, is the kitchen sink in combination with a single laundry tray, Fig. 55. In this, the drainboard serves as a cover for the tray when the sink is in use. Sinks have also been supplied in combinations with lavatories, one sink being placed in the center or at the end of a battery of lavatories.

A pantry sink, Fig. 56, should always be provided with a drain-board. It is a smaller fixture than the kitchen sink, and is nearly always of the plug-strainer and overflow type. Its faucets are generally of the high-nozzle barber-shop type, but of smaller capacity and better adapted to rinsing than are kitchen-sink faucets. Indeed, the pantry sink proper need not necessarily differ at all, unless in size from sinks used for other purposes. Every feature of its trimmings and setting is intended to best serve the butler's needs.

The waste matter from the butler's sink is not like that from the kitchen sink; hence the waste pipe is not necessarily so large, nor is a grease-trap so badly needed. Grease in considerable quantities finds its way into kitchen-sink waste pipes. It floats on the stream of waste water as it travels through the pipe, and, being always next the interior surface, either adheres thereto on contact, or by a reduction in temperature is chilled and congealed and thus clings to the pipe walls. Successive layers of grease are in this way accumulated, and the bore of the pipe is finally reduced so much that solid matter easily completes the stoppage. Forcing out, and then filling the pipe with boiling lye water, and again flushing with hot water, will usually remove most of the obstruction. Sometimes the lye loosens the grease in chunks, which clog the pipe seriously at the first favoring point, and the pipe must then be cleaned manually.

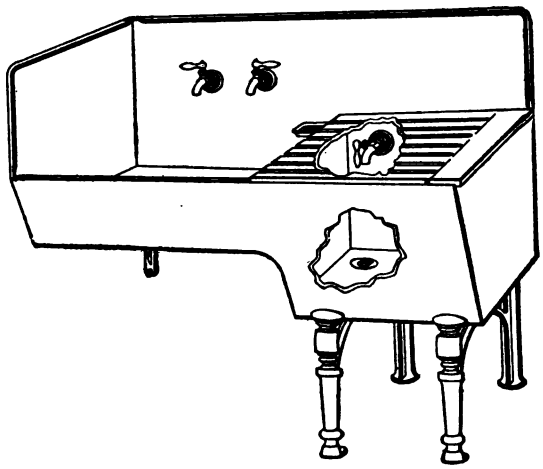


Fig. 55. **Kitchen Sink and Single Laundry Tray Combined.**

When once choked with grease, the pipe must ultimately be opened and cleaned by hand, often at material expense when long lines are deep underground. To avoid this trouble, various traps (of which two examples are shown in Fig. 57) have been designed to

separate and collect the grease, either by flotation alone or by chilling and flotation combined—generally by the former. The former were previously improvised by the plumber, being placed in the drainpipe just outside the building. This location left too much pipe subject to choking between the grease-trap and the sink; and the trap itself often became a generator of bad odors in warm weather.

The grease-traps now commonly furnished are placed in the kitchen under the sink, and frequently serve as the regular trap for the fixture. The grease is easily removed by lifting out the container or by skimming from the top. Hinged bolts with thumb-nuts secure the covers so that they can be easily and quickly opened and securely closed.

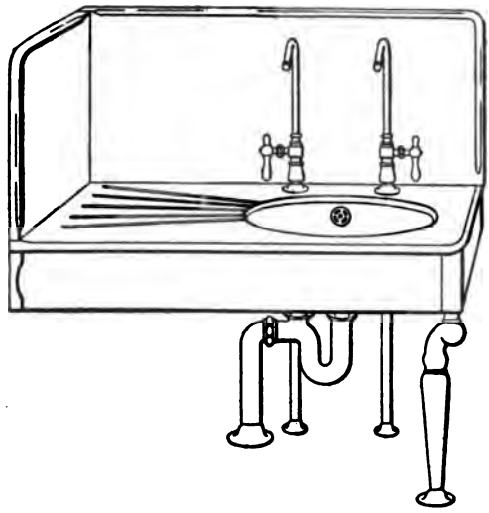


Fig. 56. Pantry Sink.

Traps which chill the grease are not used so much as those acting by simple flotation, but they do the work perfectly. The chilling process is accomplished by means of a water jacket through which the cold-water supply passes. The water entering low, surrounds the wall of the pot trap within, and passes out high up on the opposite side (see fixture at left in Fig. 57). Circulation—or, rather, change of water—in the jacket, is dependent on the amount of water used at the fixtures.

The usual slop sink is 18 by 22 inches and about 12 inches deep. Generally it is furnished mounted on a trap standard, as in Fig. 58, which serves the double purpose of support and waste-trap.

Care should be taken before installing a fixture placed upon a trap standard, to examine carefully whether the seal of the trap is provided for by suitable interior partitions. It is not uncommon to find defects in the casting, if of iron or brass—or in the porcelain, if of that material—which would seriously affect the maintenance of the

water seal. In fact, it is desirable in connection with slop sinks, as with all other fixtures, that the trap be of such a form as to show clearly, even after being set in place, the position of the various portions which constitute the trap and maintain the water seal.

The waste pipe for slop-sinks is never less in diameter than 2 inches, and is usually 3 or 4 inches. The outlet is invariably through an open strainer.

Slop sinks are made in all the materials common to other fixtures except natural stone. These sinks are to the chambermaid what the kitchen sink is to the cook. The shape and liberal-sized waste are well adapted to removing slop and scrub water. In the complete fixture, the sink is provided with an elevated tank and flushing rim

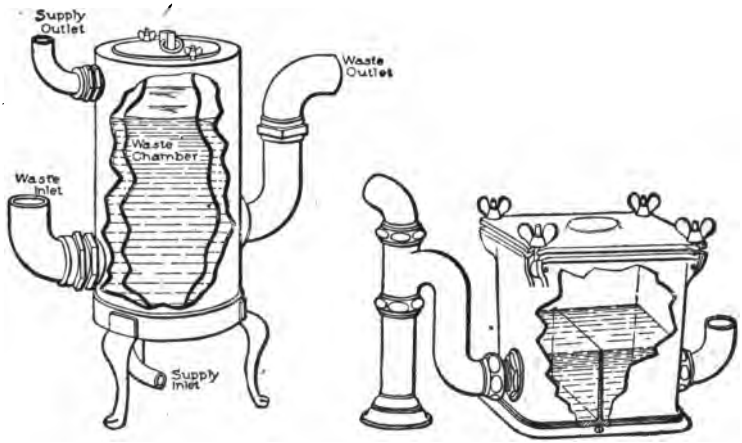


Fig. 57. Types of Kitchen Sink Traps for Separating and Collecting Grease.

to cleanse the fixture walls; also with hot and cold supplies for drawing water, rinsing mops, etc. The supplies are usually connected between the valves, and terminate with a long spout with pail-hook and brace. The spout supports the pail over the center of the sink while filling. The ordinary slop sink is provided with hot and cold faucets; and as the rims of the cheaper kinds are plain flanges, no tank flushing is possible.

Laundry Trays. These are made in all the materials used in other plumbing fixtures. Wood trays were formerly common but their unfitness because of absorption and odors, coupled with the increase in cost of lumber and the lessening in cost of the better materials, has effectually driven them out of the business.

The same inherent objection may be urged against the use of wood covers as obtains against that material for the body of the fixture.

Trays are made singly and otherwise, but generally used in sets of two or three, except in the combination with sink already described. They are supported by a center standard or a metal frame, as best suits the material used.

Fig. 58. Slop Sink Mounted on Trap Standard
Courtesy of Federal-Huber Company, Chicago

Some means of attaching wringers are provided, if possible. The waste is usually 2-inch. One trap answers for a set of trays. The size is about 26 by 30 inches at top and 15 inches deep. The walls are all nearly vertical except the front, which inclines about 30 degrees, making the width at bottom considerably less than at top. Some makers furnish one tray with each set, designed to serve as a washboard, the interior of the front wall being corrugated like the surface of a portable washboard. The inclination of the front is about right for scrubbing, whether the tray or an ordinary board is used, and the supports place the top of trays convenient to the work.

All trays were formerly made with faucet-holes in the back; and the plumber furnished a hinged cover. Side-handle faucets were necessary to allow the cover to close, as holes for top-handle faucets would be so low as to make useless too much of the space above them. The faucet-holes were seldom fitted water-tight. Holes are not now made in trays unless ordered, and the side-handle wash-tray bibb is disappearing. They were always annoying. If placed with the handles

right and left as intended, the seat could not be examined, and no reaming or dressing of the faucet seat could be done without removing the faucet. When placed with the faucet handles facing each other, they were wrong-handed and too close together. It was awkward to supply air-chambers—especially so when all the faucet holes were equidistant from the top. When placed for one line of supply above the other, one line of holes was too low. These objections combined brought about the practice of omitting the covers, putting the supplies over the trays, and using regular sink faucets. Overflows are provided only when so ordered.

Enameled backs with air-chambers and faucets are supplied with roll-rim enameled-iron trays. A complete set of three trays, with all

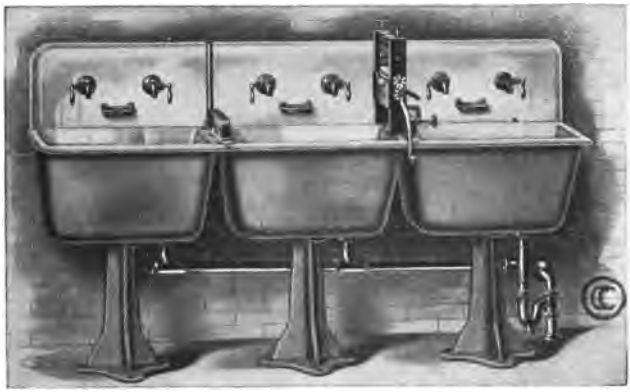


Fig. 59. Porcelain Enameled-Iron Laundry Trays with Fittings Complete
Courtesy of Crane Company, Chicago

attachments and fittings, is shown in Fig. 59. Flat-rim trays are made with or without faucet-holes, and are intended to have a hardwood frame to secure them rigidly. The wood frame and cover can be had with the fixture, but the plumber often supplies them. Nickel-plated or plain brass wastes and traps are furnished for trays, but the plumber can provide lead or cast-iron waste, if wanted.

TENTH STREET, COLON, AFTER CLEANING AND PAVING

SEWAGE DISPOSAL

Basic Principle. The subject of sewage disposal seems prosaic at first glance, but when one considers that its processes involve the whole cycle of life, the study of it becomes most interesting. It is a well-known fact that the wastes of each plane of life are destructive to the life from which they spring. One form of existence thrives on the wastes of the one above it or below it, but never on its own. All the terrible diseases of mankind have had their origin and still have their origin in the insufficient removal of the waste products. Since our population is augmenting so rapidly and the congestion in our cities and towns is increasing, the sanitary engineer is obliged daily to exercise greater vigilance in the character of the installations designed to remove these wastes.

In the study of sewage disposal systems a well-defined knowledge of bacteriology is highly important. The organic matters with which we have to deal must be changed from the unstable form in which they exist to stable chemical compounds. This result is obtained by the action of millions of micro-organisms called *bacteria*. "Without them", as Woodhead says, "the surface of the earth would be covered with dead organic matter, the remains of plant and animal bodies, which, retaining the elements necessary for the building up of new plant life and animal bodies, would soon cut off the food supply of new plants and animals; life would be impossible because the work of death would be incomplete," or, as Pasteur puts it, "because the return to the atmosphere and to the mineral kingdom of all that which has ceased to live would be totally suspended." The first discovery of the existence of bacteria is supposed to be by a Dutch lensmaker named Van Leeuwenhoek. What a revolution has been accomplished by the placing of one lens in front of another and thus bringing into play the marvelous seeing power of the microscope. The Dutchman reported, after looking through the lens, that he saw "tiny animals which moved about in the most amusing fashion." For nearly two hundred years that represented the sum of knowledge on bacteriology.

Historical. It was not until the middle of the nineteenth century that sewage disposal was studied or put into effect in a systematic way. Previous to that time, it had been the habit of individuals and communities to dispose of their sewage in a manner the least expensive and yet consistent with preventing a local nuisance, and in most cases where sewer systems had been installed, this resulted in discharging the sewage into the nearest water course. In communities not fortunate enough to have sewer systems, cesspools were abundant, and in many instances were arranged with overflows to the nearest surface drain. In 1858, conditions became so acute in England, with its small streams and large tributary population, that a law was passed prohibiting the pollution of rivers, and during the next few years several able commissions were appointed by the Government to study the problem. The commissions invariably declared that the proper method for purifying sewage was to distribute it on land, although during this period private companies were exploiting chemical processes and endeavoring to have chemical precipitation adopted as the proper form for sewage disposal. The disposal of sewage by broad irrigation was carried out on an extensive scale in England during the latter part of the nineteenth century, and several extensive chemical precipitation plants were also installed. Germany soon followed England in prohibiting the discharge of unpurified sewage into the streams and in adopting broad irrigation and chemical precipitation for treating it. America followed shortly, especially in New England, as there the small streams and dense population made the conditions quite similar to those in England.

In 1886, the State of Massachusetts passed an act preventing river pollution and placing the control of the streams in the hands of the State Board of Health. This Board constructed an experiment station at Lawrence, where extensive tests were made in the use of artificial filters, leading to the construction of the modern biological filters. Numerous experimental stations followed in England and Gemany, which resulted in many permanent installations on a large scale of artificial biological works.

In 1896, the so-called septic tanks were developed quite extensively in England, and, in the last few years, the settling tanks with separate digestion compartments have come into

TABLE I

Composition of Sewage

Analyses of Raw Sewage	PARTS PER MILLION											
	Suspended Solids			Nitrogen as				Oxygen Consumed			Alkalinity	Chlorine
	Total	Fixed	Volatile	Organic N	Free Ammonia	Nitrite	Nitrate	Total	Suspended	Dissolved		
Atlanta, Ga.	285	138	126	12.8	18.8	0.1	2.2	90.6	...	...	...	...
Columbus, O.	209	130	79	9.0	11.0	0.09	0.20	51 0	25.0	23.0	...	65
Waterbury, Conn.	165	50	115	14 8	7.8	0.14	1.52	46.0	20.0	26.0	41	48
Philadelphia, Pa.	189	59	130	6.3	4.0	0.23	1.00	76.0	35.6	40.4	128	39

prominence together with methods for the disinfection of sewage and the removal of suspended matter by fine screens.

SEWAGE

Character of Sewage. The average sewage consists mainly of water used for washing and flushing purposes. In America, the daily water consumption ranges from thirty gallons to four hundred gallons per capita with an average of one hundred gallons per capita. This water, in passing through the sewer system, contains a variable amount of solids and liquids representing the waste products of the community which altogether does not exceed two per cent of the water. If analyzed bacteriologically, it will, however, be found to contain at least one million bacteria per cubic centimeter; and if these bacteria be further differentiated, it will be found that most of them are of a harmless type. The character of sewage is naturally extremely variable, depending on the amount of water consumption per capita, the admission of storm water into the system, the character of effluent from the various industries, and the constituents of the mineral compounds in the water supply itself. It will also vary at different hours of the day.

Analyses of Sewage. Table I of analyses gives an idea of the composition of sewage. It will be noted that the quantities are expressed in parts per million by weight and that a com-

TABLE II

Typical Analysis of City Sewage

ANALYSIS OF ALLIANCE, O. SEWAGE JULY 1914
Chester & Fleming Consulting Engineers Pittsburgh, Pa.

	Sewage Flow in Million Gallons	PARTS PER MILLION — SUSPENDED SOLID: Screened Sewage	Effluent of Septic Tank #1	" " #3	DISSOLVED OXYGEN: Screened Sewage	Effluent of Septic Tank #1	" " #3	" Contact Beds	CONSUMED OXYGEN: Screened Sewage	Effluent of Septic Tank #1	" " #3	" Contact Beds	Ratio of Available Oxygen to Oxygen Required for Equilibrium Expressed in Per Cent. STABILITY at 37° C.: Effluent of Septic Tank #1	" " #3	Sand Bed #2	" " #3	" " #4
July 2	2.51	125	65	90	0	0	0	0	45	24.5	29.2	13.6					
" 3	2.52	190	80	96	0	0	0	0	50	31.6	36.4	16.0					
" 4	2.37	193	105	115	0	0	0	0	79	11.6	27.6	13.6	2	0	33	99	
" 5	2.38	185	96	174	0.6	0	0	0	30	20.0	28.0	10.8				99	99
" 6	2.57	166	116	136	0	0	0	1.7	46	25.0	40.0	11.2					
" 7	2.51	195	35	103	0	0	0	1.5	64	36.0	47.0	26.8					
" 8	2.45	150	75	135	0	0	0	1.5	49	40.0	42.0	12.8					

plete detailed analysis of the constituent parts of the sewage is not made, but totals of the solids, organic compounds, and other indicative tests are given. The form in which the organic matter exists in sewage is quite complex and would be difficult to analyze, whereas, indicative tests, which can be used for comparison, furnish the information desired.

Table II shows an analysis of sewage and effluents from the various units of sewage disposal works at Alliance, Ohio. The significance of these tests is as follows:

Suspended Solids. Dr. Imhoff divides solids found in sewage into four classes: (1) settling solids (removed by 2 hours' quiescent sedimentation); (2) finely divided solids (finer than above but removable by filtration through paper); (3) colloidal matter (finer than either of the above but removable by a dialyzing membrane); and (4) solids in true solution.

Of these, the first three are classified as suspended solids and are subdivided into fixed and volatile solids. Most of the fixed solids represent the inorganic matter in the sewage, consisting mainly of the material in the water supply. The volatile solids serve as an index of the amount of organic matter and are the solids with which we have to deal in purification.

Nitrogen. The organic nitrogen indicates the amount of undecayed organic matter containing nitrogen in the sewage, and

the free ammonia indicates the amount of decomposing organic matter containing nitrogen. The nitrites indicate a partial breaking down of the organic matter into inorganic compounds, and the nitrates indicate the amount of organic matter that has been completely broken down and changed into stable inorganic compounds.

Oxygen Consumed. A very important test as indicating the condition of the sewage with respect to stability shows the relative amount of carbonaceous organic matter in the various effluents. It is the amount of oxygen absorbed by the sewage and is used to compare with the effluent as to purification effected.

Alkalinity. The alkaline test furnishes a comparison of the sewage with the water supply, and any serious modification would indicate pollution with trade wastes of an acid character. It also serves as an index of the degree of purification by comparing sewage with effluent.

Chlorine. Chlorine is harmless in the form of common salt, in which it occurs in sewage, and is only indicative of the strength of the sewage.

Bacteria. Bacteria are microscopic organisms belonging to the vegetable kingdom. They have been divided into two classes, namely, saprophytes, which live on inanimate matter, and parasites which live on substances of animal bodies. They are further classified by their ability to thrive in the absence or presence of oxygen. Those which thrive in the presence of oxygen are called *aërobic* bacteria, and those which thrive in the absence of oxygen are called *anaërobic* bacteria. Each of the classes has so-called facultative bacteria also which exist with or without oxygen, but thrive under the conditions suited to their class. Among the subdivisions of these general classes are the pathogenic bacteria which are the means of transmitting water-borne diseases. These bacteria are of course parasites and do not increase after leaving the human body. They may exist, however, for months under most unfavorable conditions.

The reduction of organic matter to inorganic matter is accomplished by the action of enormous numbers of those bacteria upon the organic material. It has been found from experiments and from the results of the operations of numerous biological disposal plants, that *aërobic* bacteria in the presence of free oxygen bring

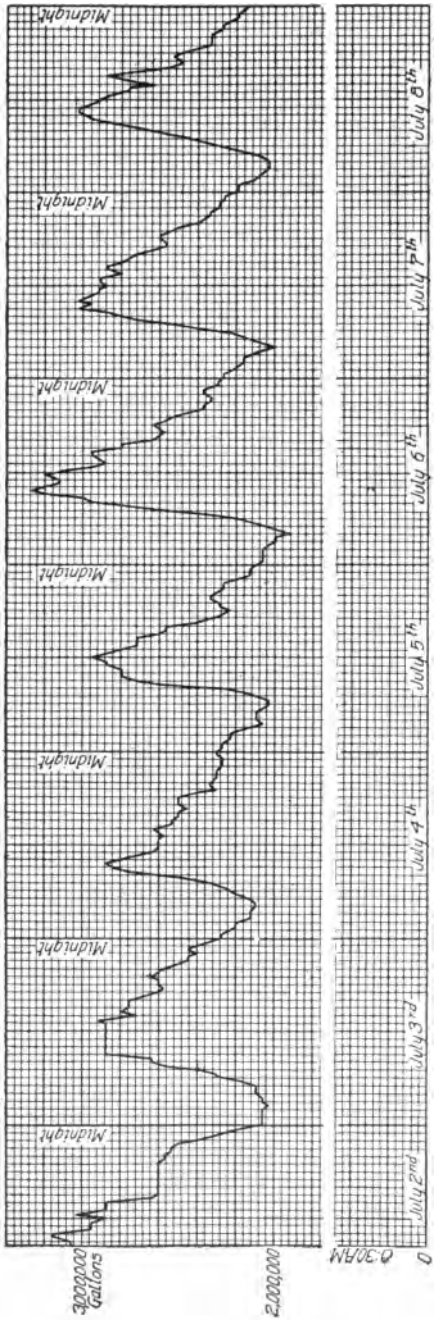


Fig. 1. Chart of Sewage Flow at Alliance, Ohio

about an oxidizing decomposition of the organic matter in sewage with but few or no objectionable odors; that *anaërobic* bacterial action, on the other hand, in the absence of free oxygen is usually accomplished with offensive odors mainly resulting from sulphurated hydrogen compounds which are formed thereby. The total number of bacteria in the sewage per cubic centimeter is indicative of the pollution, and serves as a comparison with the treated sewage as to degree of purification. Where disinfection of the sewage is desired, a count of the number of *b. coli communis* is made. This form of bacteria exists in the intestines of all animal life and is indicative of animal pollution. While it is in itself harmless, yet it is more easy to differentiate than the pathogenic bacteria, of typhoid, cholera, enteritis, and other water-borne intestinal bacteria which may or may not be present,

and as these bacteria are less hardy, the removal of *b. coli* is an indication of the removal of harmful bacteria.

DISPOSAL SYSTEMS

Requirements of Sewage Disposal. The requirements as to sewage disposal are varied for there are few cases where the conditions are the same. A study must be made of the conditions in each particular case, taking into consideration the location of water supplies; other industries which might be affected; the capacity and nature of the stream into which the sewage is to be discharged; the condition of the sewage itself; the possibilities of elimination of storm flows; and of the suitable location of treatment works. The variation of the hourly flow of the sewage must also be studied where treatment works are to be installed and data obtained on the amount of storm water admitted during rains.

Fig. 1 shows the weekly flow of the sewage at Alliance, Ohio. During the wet season this flow is tripled for brief periods.

There are many towns on large bodies of water where disposal by dilution is entirely feasible. On smaller streams, a partial purification in the nature of the elimination of solids or disinfection, or both, may be satisfactory, and in other cases, on small streams or in locations immediately above important water supplies, the highest degree of purification must be effected, including the removal of all organic matter and the disinfection of the bacterial content.

Classification of Methods. The methods employed in disposal of sewage are dilution and purification. The methods of purification now in use consist of broad irrigation, chemical precipitation, screens, settling tanks, septic tanks, contact beds, sprinkling filters, sand filters, disinfection, and electrolytic treatment. Each of these methods may be subdivided into various types, but in this book it is the intention in describing them, to outline only the most widely used and successful type under each. In considering the different methods, it is to be understood that one or more may be necessary to solve the problem, as will be outlined hereafter.

DILUTION

Controlling Factors. Nearly all of the larger cities of America dispose of their sewage by dilution. This is due to their location on the seaboard or large rivers.

For the proper dilution of sewage, there must be a volume of water sufficient to permit of *aërobic* bacterial action which will effect a complete breaking down of the organic matter and at the same time not destroy fish life; or in other words, the oxygen content of the stream must not be materially reduced. The minimum is set by authorities at from 30 per cent to 70 per cent of the saturation volume. The amount of water required to attain this result depends on the amount of dissolved oxygen in the stream and conditions for replacing it. Leading authorities estimate this at from 4 cubic feet to 10 cubic feet per second per 1000 tributary population. There must also be current sufficient to prevent silting-up of the stream or bay, and it is also important that there be no inshore currents which will deposit floating material on the shore lines. Large quantities of trade wastes from industries may kill fish life and must therefore be considered. The distance required to complete the purification by this method varies also with the character of the stream. A mountain stream with many waterfalls will manifestly purify itself much more quickly than a sluggish lowland river. There are no signs of pollution of the Mississippi at New Orleans and yet it receives above this point, the sewage of over 10,000,000 people. However, for the last 600 miles it travels through delta country where the drainage is away from the river.

Dilution of Chicago Sewage. The Chicago Drainage Canal is a notable example of disposal by dilution. This canal was constructed at a cost of $64,000,000 to divert the flow from the lake harbor through the Chicago River to the Illinois River, a tributary of the Mississippi. The sewage is diluted on a basis of 3.3 cubic feet per second per 1000 population, although the engineers in charge recommended a minimum of 4 cubic feet per second.

The Illinois River enters the Mississippi 357 miles from Chicago, a few miles above the St. Louis Water Works Intake. In a suit brought by the city of St. Louis to prohibit this arrangement, extensive tests showed that there was no substantial pollution from this source. Recent reports show, however, that for a distance of one hundred miles from Chicago along the Desplaines and Illinois rivers there is a very unwholesome condition and that along the Chicago River there are serious nuisances. Recommendations have been made to remove the solids before dilution.

Other Examples of Dilution. The sewage of New York is discharged through many outlets into New York Harbor. This has resulted in considerable deposits of silt at many points and studies are now being made of a partial purification of sewage from this metropolitan district.

The sewage from the main district of Boston is carried by an outfall sewer to an island in the outer harbor where it is stored in basins and discharged only during the early hours of the outflowing tide.

Many of the lake cities have long outlet sewers into the lake to prevent silting-up and deposit of solids on harbor front, and also to insure proper dilution.

BROAD IRRIGATION

General Principles. Broad irrigation is the oldest type of scientific purification of sewage. It has been practiced on a large scale in England and Germany, and several installations have been made in America. It consists in applying the sewage by a system of ditches to farm areas with the idea of irrigating them and also obtaining the fertilizing value of the sewage. The principle is that of *aërobic* bacterial action by natural filtration, and depends for success on a light and preferably sandy soil and on being able to operate uniformly at all times and seasons without overloading the treated area. An acre of area is the average requirement for each one hundred of tributary population. When this method first came into use, it was predicted that considerable profit would be derived. It has, however, been found that in the wet seasons it is very difficult to take care of the sewage and prevent water-logging the crops without by-passing the sewage; and that as a result the crops that can be raised are limited, and the fertilizing value of the sewage does not justify the expense required to apply it properly.

Efficiency of Broad Irrigation. The results obtained from well-operated irrigation farms are excellent. The effluent is stable with a marked reduction in bacterial count and in many instances showing absence of *b. coli.* Dr. Dunbar states that he is convinced that it would be cheaper for many towns to abandon irrigation and replace it with artificial biological processes and that

the day is not far off when Berlin will sell its irrigation farms for building purposes and construct artificial biological filters.

This is the attitude of all sanitary engineers at the present time. The only condition where it can now be favorably considered is in a district with low rainfall where irrigation is necessary for crop raising, and when the soil is adapted to irrigation.

CHEMICAL PRECIPITATION

Controlling Factors. The method of sewage disposal by chemical precipitation was introduced by various private companies under patents at about the same time that broad irrigation came into use, and there have been some large installations in England, Germany, and America.

The sewage is introduced into settling tanks where it is treated with chemicals such as sulphate of iron and lime. These chemicals form a heavy flocculent precipitate which settles in the tanks and carries with it a part of the suspended matter in the sewage. The precipitated material, or sludge, is then drawn off and usually compressed by sludge presses so as to remove the water and facilitate handling.

Efficiency of Chemical Precipitation. It has been found that 90 per cent of the total suspended matter and bacteria can be removed from sewage by this process. The effluent is putrescible as there has been no change in the remaining organic matter.

When this process was first installed, fabulous claims were made of the value of the sludge as fertilizers from plants of this type. This has been much overrated and it is difficult to get farmers to come to the plants and haul it free. Many such plants have to deposit the sludge in fills and as the amount will average 5 cubic yards per million gallons of sewage treated, there is a considerable quantity for a town of any size. The high cost of chemicals and labor required in the operation has also been against this method which is no longer being installed for municipal disposal works.

Conditions Favoring Chemical Precipitation. There are some circumstances in dealing with trade wastes or some special conditions, such as at London, under which the chemical process can be used to advantage.

It has been necessary at London to remove the suspended matter to prevent the silting up of the Thames. This has been accomplished by treating the sewage by chemical precipitation amounting to 200,000,000 gallons daily in nineteen settling tanks having a combined capacity of 44,000,000 gallons. About 8,000 cubic yards of sludge is deposited daily. This is pumped into tank steamers and carried out to sea.

SCREENS

Purpose. Coarse screens are in general use at sewage pumping stations and disposal works to remove the coarse suspended matters. During the last few years, mechanically operated fine screens have been developed in Germany which can remove as high as 80 per cent of the suspended matter from the sewage. These fine screens are now being introduced into America.

Coarse Screens. The most common type of coarse screen is the bar screen consisting of vertical steel bars spaced from $\frac{1}{2}$ inch to $1\frac{1}{2}$ inches apart depending on conditions, and arranged in a masonry pit at the outlet end of the sewer across the line of flow of the sewage. The fibrous materials in the sewage make the problem of cleaning a difficult one and screens must, therefore, be installed in duplicate so that one can readily be removed. For small plants, the screens are usually cleaned by the attendant pulling a garden rake up over the vertical bars several times daily. In large plants, one screen is removed from the pit by hoists or hydraulic lift and cleaned with a hose on the operating floor above, or some form of mechanical cleaning device is used.

The material obtained from coarse screens consists of rags, paper, sticks, lemon peels, and other coarse organic matter. This is usually placed in large cans and hauled to a dumping ground where it is buried. If the city owns an incinerating plant, it can be mixed with the garbage and burned.

Fine Screens. There have been many types of fine screens developed, with varying success. The best known type at the present time is the Reinsch-Wurl screen as shown in Fig. 2. These screens consist of a large circular plate which is placed at an inclined angle in the outfall sewer and is revolved about its center. This plate is perforated over its entire surface with fine

slots. The size of slot and diameter of plate vary with the amount of sewage to be treated and the degree of purification to be effected.

Fig. 2. Reinsch-Wurl Screen in Experimental Plant, Dresden, Germany

As the plate revolves, the deposited solids are brought above the surface of the sewage, Fig. 3, and are then brushed off the plate

Fig. 3. Reinsch-Wurl Screen in Operation at Bremen, Showing Brushes

by metallic brushes which sweep the screenings into a trough where it is transported to the sludge presses or carted away.

Fig. 4. Installation of Reinsch-Wurl Screens at Dresden, Germany

The amount of power required to drive this apparatus is small and the installation is much less expensive than settling tanks. There are the difficulties, however, of a higher operating cost and the problem of the distribution of the screenings. The screenings can be disposed of as outlined under the paragraphs on coarse screens, but on account of their amount, it is preferable to make some arrangement regarding their use as fertilizers with the farmers, who will take them free unless there is local prejudice. While these screenings have some value, yet they must be removed daily and disposed of immediately before putrefaction sets in, and farmers will not agree to an annual contract on better conditions than free material, on account of the difficulty of distributing it in winter weather.

The plant at Dresden, as shown in Fig. 4, is the largest plant of this type in the world. It was installed in 1911, and treats a maximum flow of 4500 gallons per second. For three months in 1911, the Elbe, into which the effluent is discharged, had a flow of less than one-half that of the incoming sewage and yet no nuisance was caused thereby.

These fine screen installations are specially adapted to use where clarification alone is required for conditions under which it is necessary to install the purification works adjacent to a built-up district. The fresh screenings have not had time to putrefy and can be hauled away easily without offense. They are also used for clarification and the recovering of by-products of industrial waste, and under special conditions for screening sewage to be treated by filters.

SEDIMENTATION TANKS

Efficiency. The method generally used for clarifying sewage is by natural sedimentation. This will remove from 50 per cent to 75 per cent of the total suspended matter from the sewage and 35 per cent of the organic matter, leaving the effluent with the balance of the organic matter in solution and in suspension as colloids. Sedimentation is used as a method of clarifying sewage before it discharges into a stream where dilution is feasible, or as the first step in complete purification.

Classes. There are three general classes of sedimentation tanks: (1) grit chambers; (2) settling tanks; and (3) septic tanks. These classes have various modifications and designs.

Velocity. Practically all designs are based on a continuous flow through the tanks at a velocity sufficiently low to deposit the suspended matter. Extensive experiments have been made to determine the carrying velocity of sewage-laden water, and as a result of these experiments authorities place the maximum velocity for settling tanks at one-half inch per second, and the average velocity of grit chambers at 1 foot per second.

Grit Chambers

Use. Grit chambers are used on combined sewer systems or sanitary systems which admit some street drainage, in order to remove the coarse organic suspended matter before it has reached the pumps or disposal works. Where the sewer system carries only house drainage, they are unnecessary.

Design. They must be designed so that no organic matter will be deposited and so that the period of retention is not long enough to start septic action. A velocity of 1 foot per second will deposit the grit without the organic matter and the period of retention may vary from a few seconds to 5 or 10 minutes, depending on the coarseness of the material. Where the amount of sewage varies at different times, several compartments must be installed with automatic overflow weirs so that the velocity and period of retention may be uniform. The usual design is rectangular in plan with length sufficient to give the required period of retention and velocity, and with a cross-section suited to securing a uniform velocity over the entire area without complicated baffling. The bottom should be sloped on a 10 per cent grade to an outlet drain controlled by a valve. The details of design are very similar to those for the more complicated settling tanks, which will be hereafter described. The depth used, however, is comparatively shallow, as grit chambers must be cleaned frequently, and too much surplus storage capacity would affect the uniform velocity desired.

Settling Tanks

Settling vs. Septic Tanks. Settling tanks can be distinguished from septic tanks by the fact that putrefactive action in the latter results from the action of *anaërobic* bacteria on the organic matter retained therein. An arbitrary definition of septic

tanks has been that they must have an uninterrupted flow without removal of sludge for at least six weeks. However, newly cleaned settling tanks have shown signs of septic action in a few days after being placed in commission. Settling tanks retaining their solids are, however, usually distinguished from septic tanks by the frequent cleaning periods in the former case, and the six weeks' period is usually taken as the dividing line.

Basic Conditions. Settling tanks may be divided into two classes, single-story tanks and two-story tanks. The governing criteria for both classes are a maximum velocity of one-half inch per second, a minimum retention period of one hour, and a minimum distance of horizontal travel of 35 feet.

Single-Story Settling Tanks. *Design.* The usual type of the single-story settling tank is rectangular in plan and has a continuous horizontal flow lengthwise through the tank. Several compartments are constructed to permit one or more tanks to be used in proportion to the flow of sewage and to permit tanks to be cleaned without interfering with the continuous operation of the plant. The depth of tanks should preferably be 12 feet to 16 feet to give ample room for storage of sludge without its being disturbed by the flow of sewage. Their capacity should be a retention period of from 1 hour to 4 hours with additional time sufficient for sludge storage. Their length and width are governed by the number of units, the capacity and limitation of velocity and horizontal travel given above. The length does not usually exceed 100 feet and the width is usually $\frac{1}{8}$ to $\frac{1}{10}$ the length. Covers over tanks are not necessary, although they are usually installed on well-designed tanks for the sake of appearance. If covers are used, vents must be installed for gases. It is important to obtain a uniform distribution of the sewage across the entire cross-section and to maintain a uniform velocity. This is accomplished by distribution across inlet and outlet ends and by one or more baffles across the tanks. It is very necessary to design the tanks so that they can be cleaned easily. The bottoms must be sloped on a minimum slope of five per cent to a central sump where the sludge can be drained by gravity to a sludge bed or can be pumped. A fire hose with water under good pressure is indispensable in economic cleaning. The sludge bed must be constructed of gravel or other porous

material and be well underdrained. The minimum depth must be at least 12 inches, and the surface must be covered with a minimum depth of 2 inches of sand to retain the sludge. The sludge bed must be of area sufficient to permit the sludge to be deposited with a maximum depth of six inches so that it can dry. With this depth it will dry under favorable conditions in from one to two weeks. With well-digested sludge, an area of 0.3 square feet per inhabitant is sufficient.

Sludge. The sludge problem is the most serious one to be considered with settling tanks. If they are frequently cleaned, this highly putrescible organic matter must be discharged onto the sludge beds every few weeks, causing very disagreeable odors; and when the sludge is scraped off after drying, it must be disposed of. Where the number of tanks is sufficient to permit, one should be placed out of commission so that the sludge can digest in the tank before being discharged, as a period of several months is required to obtain thorough digestion. This is accomplished by the action of *anaërobic* bacteria, which usually produce offensive gases and cause a highly septic liquid in the tank above the sludge. It is therefore dangerous to install plants of this type within half a mile of residences.

Septic Tanks

Basic Conditions. These tanks are the same as the single-story settling tanks previously described, except that septic action or the action of *anaërobic* bacteria is desired. The tanks are designed with a capacity of from four hours' to twenty-four hours' settling period so as to insure capacity enough for sludge storage. In America the maximum is twelve hours. The flow through the tanks is continuous and at a slow velocity, exactly as described for settling tanks.

As the sewage flows slowly through the tank, the coarser suspended matter settles to the bottom where it is attacked by millions of *anaërobes* which have developed on the sludge previously retained. Lighter particles rise to the surface forming a thick heavy scum over the entire surface. Small atoms breaking off from this sink to the bottom, while light ones rise from below, impelled by gases. All these are teeming with *anaërobes* which are liquefying and gasi-

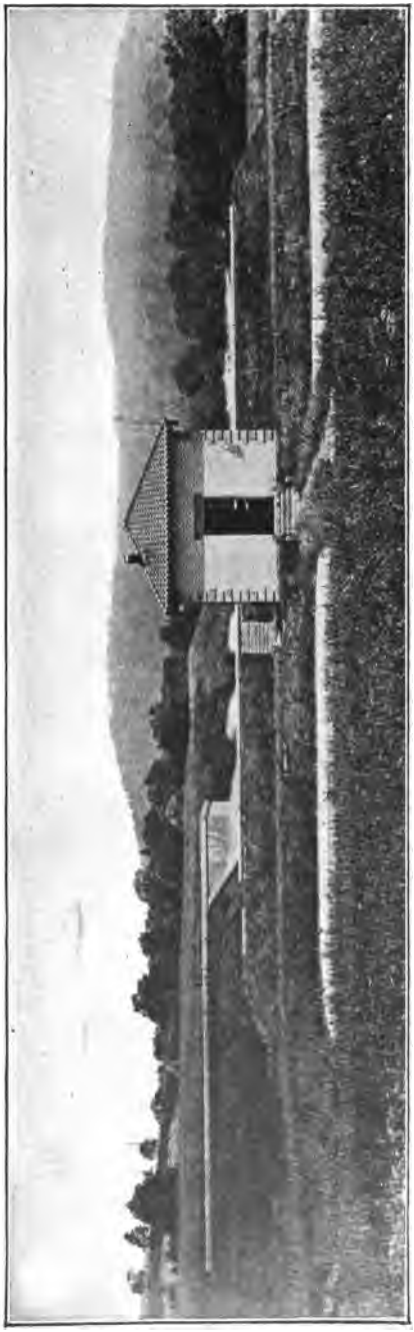


Fig. 5. General View of Sewage Disposal Plant at Polk, Pennsylvania

fying the organic matter. In septic tanks sludge is only removed when there has been an accumulation such that it overtaxes the sludge capacity. Where *anaërobic* action works perfectly, the greater proportion of the suspended matter is liquefied, and it has been found that after retention for three or four months the remaining sludge is inodorous, while in many cases it is removed once a year with little or no nuisance. The difficulties experienced with septic tanks are from the offensive gases usually present in the tank effluent. These gases are liberated when the effluent is discharged onto the biological filters, with resulting nuisance to adjacent property. The oxygen content of the sewage is also removed, which places it in bad shape for *aërobic* treatment either by dilution or filtration.

Where septic tanks work perfectly with no attendant odors in the effluent, they furnish one of the best methods for removing the suspended matters. Most of the single-story settling tanks in America are

operated as modified septic tanks. The storage capacity of the sludge is in many cases limited, requiring frequent removal of same, but there is considerable liquefaction and the sludge is fairly stable. It is difficult, however, to prevent fresh sludge that has just been deposited from being drawn off with the more thoroughly digested material under these conditions.

Polk Tanks. Figs. 5 and 6 show an installation of settling tanks of this type which are used to remove the suspended matter before the sewage is applied to sprinkling filters. Figs. 7 and 8 show the details of these tanks.

This plant was designed to purify the sewage from one of the largest state institutions in Pennsylvania and to discharge it into

Fig. 6. Covered Settling Tanks of Polk Disposal Plant

a small stream of practically pure water where it was impossible to obtain a flow in the dry season sufficient to render the effluent from the sewers inoffensive or properly diluted. The plant was designed to treat daily five hundred and sixty-four thousand gallons. It consists of screen chambers, settling tanks, sprinkling filters, and disinfection apparatus for the disinfection of the effluent with chloride of lime.

There are four settling tanks, Fig. 6, each 80 feet long by 16 feet wide by 10 feet deep, and each with a capacity of 96,000 gallons, which permits a settling period of 12 hours with three tanks in operation.

As will be noted in Figs. 7 and 8, the sewage is admitted into a reinforced-concrete distributing trough extending across

the inlet ends of the entire group of tanks, from which sewage can be admitted into one or more compartments through two or three

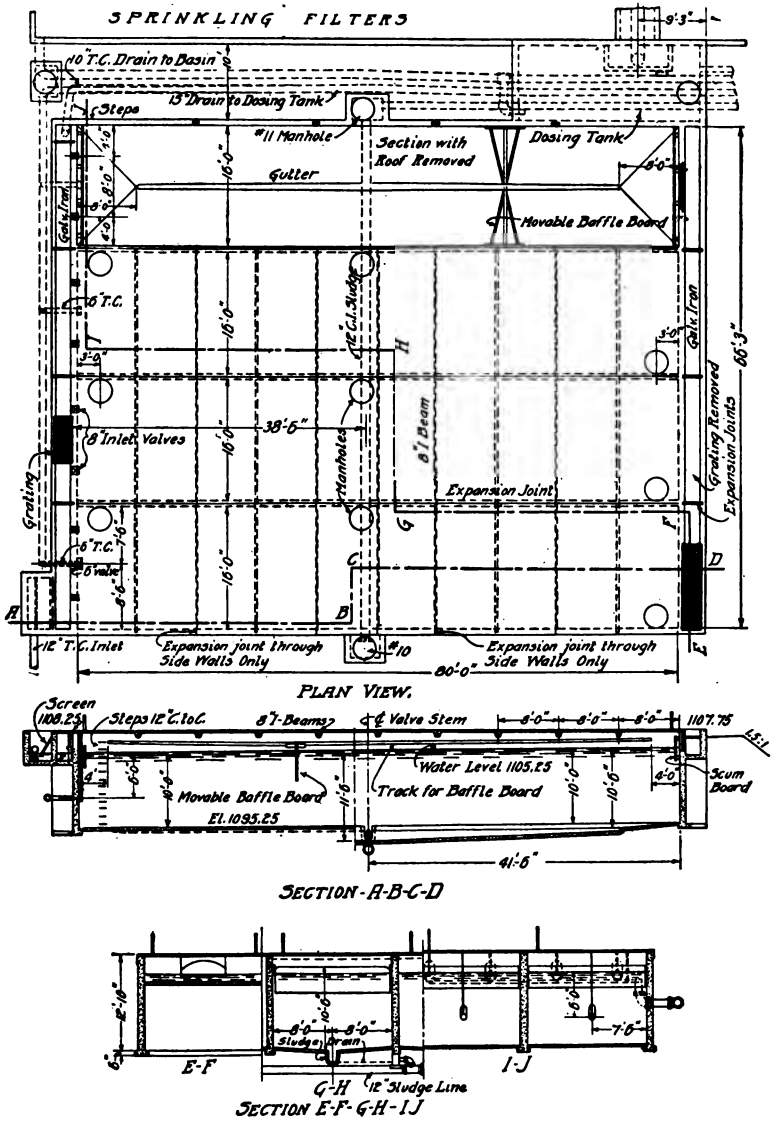


Fig. 7. Detailed Plan and Sections of Covered Settling Tanks

gate valves located immediately below the flow line. A distributing baffle of wood is constructed across the inlet end of each tank oppo-

site these gate valves at a distance of 10 inches from the wall and extending to a depth of 2 feet below the flow line. This baffle distributes the sewage uniformly across the inlet end of the tank. At the outlet end of each tank the sewage is removed over a steel weir 6 feet long located at the flow line of each compartment and at the center of the wall. This weir is also protected by a wooden

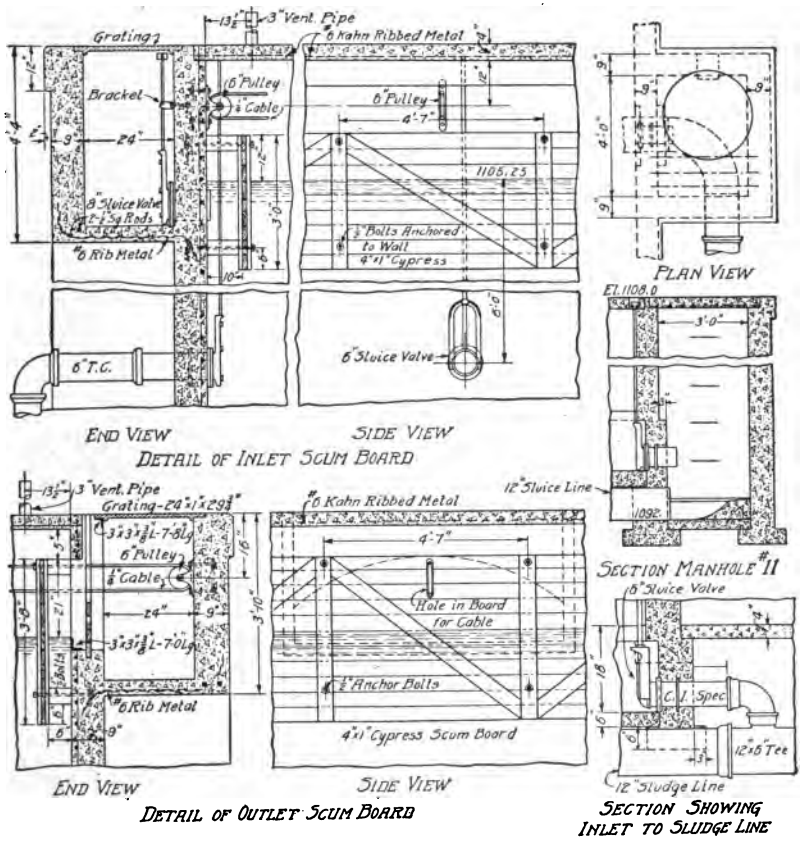


Fig. 8. Diagram Showing Special Details of Polk Covered Settling Tanks

baffle to assist in taking off the sewage uniformly from the entire width of the tank and to protect the outlet from floating material or from solid matter that may be working up from the bottom of the tank because of septic action.

A movable wooden baffle extending 4 feet 6 inches below the flow line is suspended on a trolley running the length of the tank

and can be located at any point between the inlet and outlet ends as may be desired. This baffle is also used to prevent cross-currents and to assist in a uniform flow through the tank. It will be noted by further reference to the illustrations that stop planks are arranged on the outlets of the various compartments and on the inlet and outlet troughs opposite the partition walls between the tanks. By adjusting these stop planks the tanks can be operated in series instead of in parallel.

It will be noted that, for the purpose of cleaning, the concrete bottom of each compartment slopes on a 5 per cent grade to a gutter extending lengthwise through the center of each tank, as shown in section *G H* in Fig. 7. The bottom of this gutter is also placed on a 5 per cent slope and at the center of the tank there is a 6-inch valve connection for draining off the sludge to a 12-inch sludge line, extending under the tanks and carrying the sludge by gravity to sludge beds. It will also be noted that the tanks are covered with concrete roofing and that the inlet and outlet troughs are covered with cast-iron gratings which serve to improve the general appearance.

This plant has been in operation for over five years, and the results obtained from these settling tanks have been highly satisfactory. They have maintained uniformly over fifty per cent removal of the suspended matter and there has been a very small accumulation of sludge, most of it being liquefied in the tanks. A small amount is removed at frequent intervals and discharged on the sludge bed and when dried is scraped off and plowed into adjacent ground. There have been no complaints of offensive odors and practically no trouble from gases liberated by *anaërobic* action. The plant is, however, well isolated, being three thousand feet from the institution. It is typical of the higher grade settling tanks in America and if it were not for the frequent removal of sludge, thereby preventing complete septic action, it would be typical of the septic tanks.

Two-Story Tanks. *Basic Conditions.* The problem of eliminating the nuisance arising from the use of settling or septic tanks where offensive odors are in many cases given off by the effluents due to the *anaërobic* action in the compartments, and the difficulties experienced in handling the sludge and obtaining thorough

digestion of it before it is removed from the tanks, has resulted in the development of a type of tank where the sewage flowing through the tank is kept entirely separate from the deposited suspended matters. It has been found also that septic action does not benefit the liquids for the secondary treatment on the biological filters, but that in fact it is preferable to get the liquids to the biological filters in a condition as fresh as possible, in order to retain some oxygen which would be favorable in the secondary treatment. The typical tank of this type is the Imhoff tank developed by Dr. Karl Imhoff, the German expert.

Design. In this type of tank the sewage flows through an upper compartment under the conditions previously specified

Fig. 9. Installation of Imhoff Tanks at Atlanta, Georgia

for travel and velocity, but with a retention period of from one to four hours. The compartment is equipped with a sloping bottom placed on a slope of not less than 1.2 vertical to 1 horizontal, and terminating in a sealed slot, with a lap horizontally of at least 8 inches. This slot discharges into a lower compartment that has no connection with the upper compartment other than the sealed slot. This lower compartment is designed to retain a capacity of at least six months' sludge, based on a capacity of 1000 cubic feet per thousand inhabitants. The lower compartment is usually built cone shape, terminating in a sump at the bottom from which there is a discharge line for the sludge bed. There must also be an opening from the compartment to the surface as a discharge for gases and as an admission for cleaning. As the sludge is drawn

from the bottom of the compartment, and as there is six months' capacity for *anaërobic* action, if the sludge is drawn off in small

Fig. 10. Interior View of Imhoff Tanks at Batavia, New York

Fig. 11. Installation of Imhoff Tanks at Essen, North Germany

quantities at intervals of six weeks, only thoroughly worked over sludge will be placed on the sludge beds and the result is that there can be no nuisance.

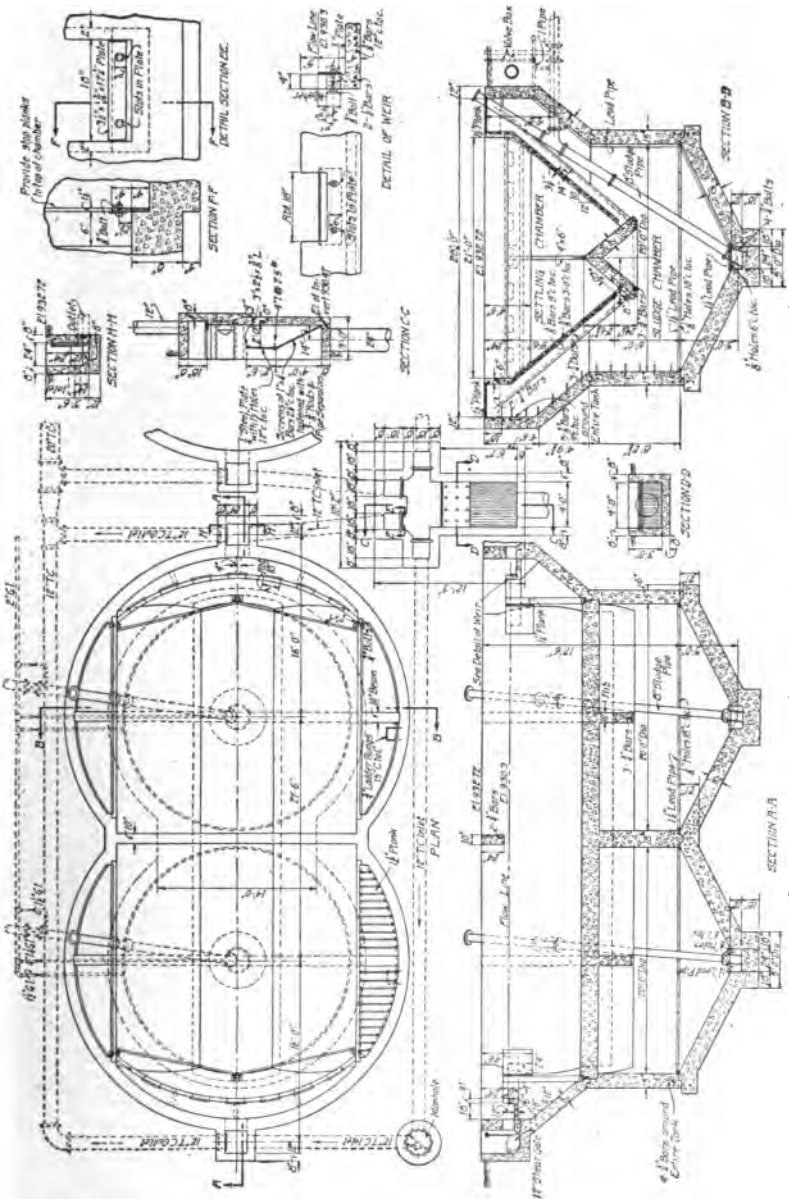


Fig. 12. Plan and Sections of Imhoff Tanks at Greenville, Pennsylvania

Operating Results. Figs. 9 to 11 show installations of this type of tank at — Atlanta, Georgia, Fig. 9; at Batavia, New York, Fig. 10; and at Essen, North Germany, Fig. 11. The Atlanta plant was placed in service in 1912, and the result of the operations for the years 1913 and 1914, which was recently published, showed an average removal of total suspended matter by the Imhoff tanks of 80 per cent. The average period of retention in the flow of sewage was two hours. The plant at Batavia, New York, which was installed in 1912, is also giving excellent results. No nuisance has been noticed at either plant and the sludge removed from the tanks has been well-digested and inodorous.

Greenville Tanks. There are various forms of design for the Imhoff tanks. Fig. 12 shows the plans for the Imhoff tanks to be installed for Greenville, Pennsylvania. These tanks are of the circular type, constructed in pairs and arranged for a longitudinal flow through each pair. Piping facilities provide for reversing this flow, a necessary operation every few weeks in order that the deposited material may be uniformly distributed in both tanks. The entire capacity of this plant is one million gallons per 24 hours based on a settling period of 1½ hours, and on a sludge storage of 6 months for seven thousand people. Imhoff tanks are constructed of reinforced concrete and the arrangement for admitting sewage to the tanks and reversing its flow is by means of cast-iron pipe lines controlled by concrete manholes with stop planks as shown. Sewage is distributed across the inlet end of the tank by concrete weirs spaced uniformly along the outer edge of a trough of the same material built across the entire width of the tank at the inlet end and protected by a wooden baffle extending to a depth of 24 inches below the flow line. This baffle serves to distribute sewage uniformly across the entire tank. Sewage is taken off at the opposite end of the pair of tanks by a concrete trough similar to the one described, also protected by a skimming baffle. The upper compartment is separated from the lower compartment by a reinforced-concrete slab, terminating in two slots on each side of a wedge frame built at the bottom of the compartment as shown. (See section *BB* of Fig. 12.) It will be noted in the design, that the upper or settling compartment is common to the two tanks, but that the lower or sludge compartments are entirely independent

of each other. The sludge is removed from a sump at the center of the sludge compartment of each tank by means of an 8-inch sludge pipe extending to within a few feet of the flow line of the tank, where it is connected by a valve to a gravity drain extending

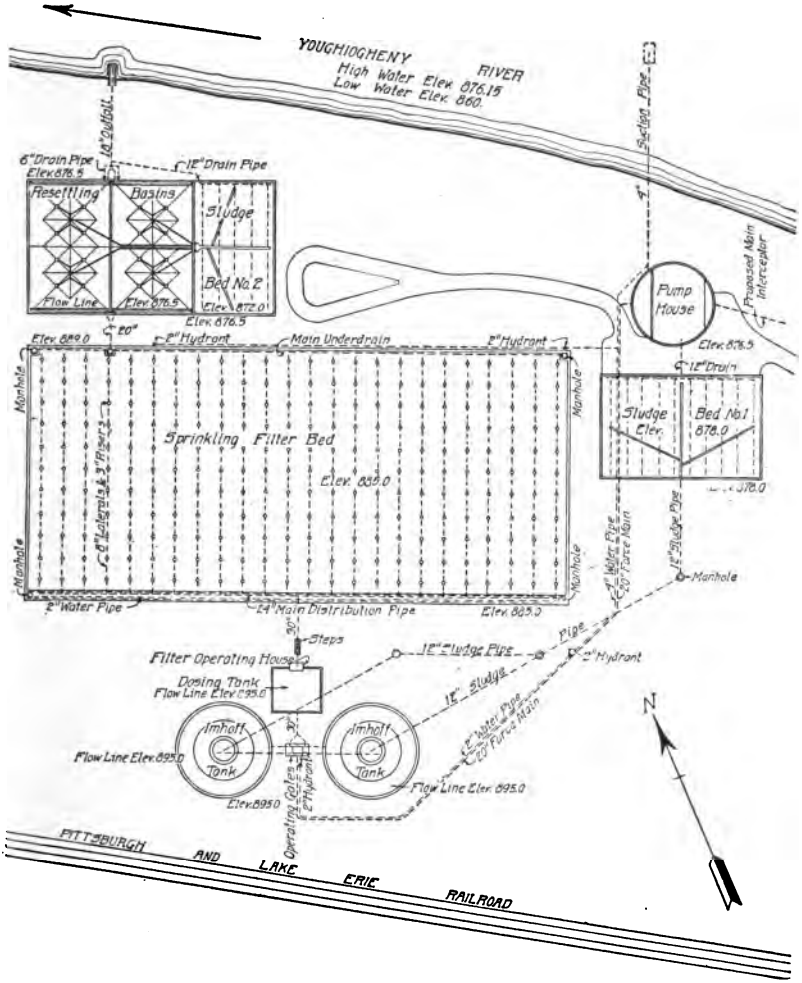


Fig. 13. Plan of Sewage Disposal Plant at Connellsville, Pennsylvania

to the sludge bed. Without interfering with the operation of the tank, sludge is removed by hydraulic pressure in the tank upon opening this valve. It will be further noted by reference to the illustration that ample area is left along the sides of the settling

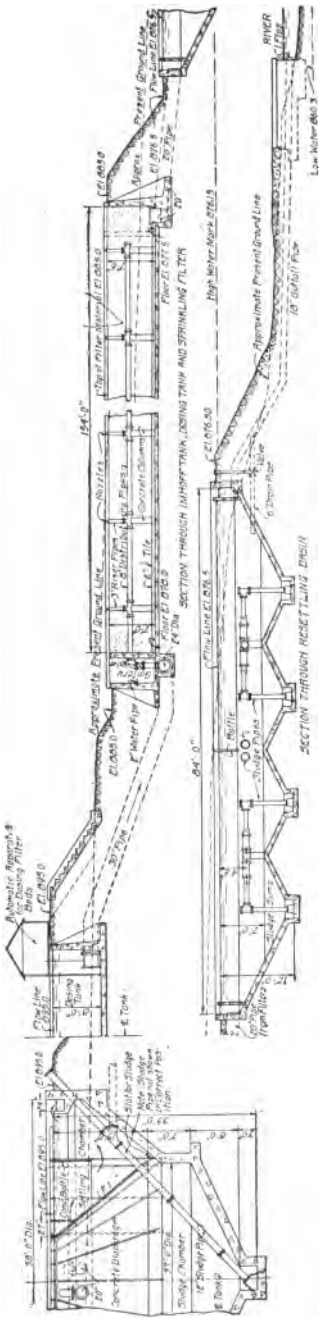


Fig. 14. Section of Sewage Disposal Plant at Connellsville, Pennsylvania

compartment at the top of the Imhoff tanks for ventilating the lower compartment. These compartments are covered with removable wooden gratings as shown.

Radial-Flow Tanks. Figs. 13 and 14 show a typical design of what is known as the radial-flow Imhoff tanks. These tanks were designed for a sewage disposal plant for Connellsville, Pennsylvania, a town having a population of sixteen thousand and a flow of sewage of three million gallons per 24 hours. Two radial-flow Imhoff tanks are planned for this installation. They are designed for two hours' capacity in the settling compartment and for a six months' storage of sludge, and are to be constructed of reinforced concrete. Sewage will be admitted through a manhole between the tanks, Fig. 13, from which it will be diverted to one or both of the tanks by means of stop planks controlling 20-inch cast-iron pipes extending to the circular trough near the center of each tank. This circular trough will be 14 feet in diameter and 27 inches wide, and will have slots in the bottom of it spaced uniformly around the circumference at a depth of 3 feet below the flow line. The diameter of each tank will be 58 feet. The settling chamber will be separated from the sludge chamber by a cone diaphragm of concrete as

shown, with a slot located at the bottom of the diaphragm, between it and the outside sloping wall of the tank. Halfway across the settling chamber between the circular inlet and outlet troughs, there will be a concrete baffle extending to a depth of half the tank at this point from the top. The outlet trough will be arranged with outlet weirs spaced along the top of the trough at uniform distances and at the same level. The sludge compartment will be drained by a sludge pipe extending from a sump at the center of the compartment to a gate valve located outside of the tank and 5 feet below the flow line. By opening this valve the sludge will be drained by hydraulic pressure without interfering with the operation of the tank.

Flushing. One of the most important adjuncts to equipping Imhoff tanks is a good fire hose with plenty of water pressure, and with facilities for applying it to any portion of the tanks. This is valuable in breaking up or removing any scum formation in the settling compartment, in keeping the sludge pipe clean, and in washing off any compartment which may be drained.

CONTACT BEDS

Use. Contact beds are a type of the biological filters generally used for treating sewage from which most of the suspended matter has been removed by sedimentation or by fine screens. They are employed to further remove additional organic and suspended matter and to render the effluent non-putrescible.

Basic Conditions. Contact filters are constructed of broken stone, hard slag, or well-burned cinders, preferably of material ranging in size from ¼ inch to 2 inches. The filters are usually of an effective depth of from 1 foot to 5 feet, depending on the amount of head available. The best depth is 4 feet to 5 feet and with this depth a maximum flow of 700,000 gallons of clarified sewage can be treated per acre. As a general rule 150,000 gallons per acre is the maximum amount that can be treated for each foot of filter depth. The beds must be operated so that they will be frequently filled with air, as the action is entirely that of *aërobic* bacteria. These bacteria exist in enormous numbers over the surface of the filtering material throughout its entire depth. When the sewage is placed in contact with this filtering material, the remain-

ing suspended matter in the sewage consisting mainly of colloids and non-settling solids, is to a great extent retained in contact with the filtering material by attrition; and the enormous bacterial growths of *aërobic* bacteria attack this organic matter, quickly reducing it to inorganic forms.

Design. Most of the contact filters installed in America are operated on the fill-and-draw method, being controlled by automatic apparatus which admits the sewage to one unit of a group of filters and when this is full opens up the outlet from it, and at the same time starts the sewage flowing into the next filter. These filters must be constructed as water-tight compartments and are usually built of concrete. The number of groups to be used and the size of units in each group depend upon the amount of sewage to be handled and the depth of filter desired. It is usually not desirable to have the units larger than a quarter of an acre each, and, on the other hand, it is advisable to have at least four units in order to secure long resting periods between the dosing. It has been found that the period of retention has very little to do with the efficiency, so that in most installations, the apparatus is arranged in such a way that the tank starts to empty a few minutes after it has filled.

Alliance Filters. Figs. 15, 16, and 17 show a plan of the plant and the contact filters of Alliance, Ohio, and the automatic control apparatus for one group.

As will be noted upon reference to the plans, the Alliance filters are designed to treat sewage clarified by settling tanks. They have a capacity for two million gallons of sewage per day. They consist of three groups, each with a total area of one acre and subdivided into four filters. Each filter has an effective depth of 5 feet and consists of a concrete compartment filled with well-burned cinders and underlaid by tile drains upon the floor, which drain to the central control chamber. The sewage flows from the settling tanks to the central control chamber of each group of contact beds, where it is distributed by automatic air-lock apparatus on to each bed at the surface. This apparatus consists of Miller-Adams siphons, each of which is controlled by an air bell which can break the siphon seals. These air bells are located in concrete compartments and connected by small pipes to the siphons. As the water

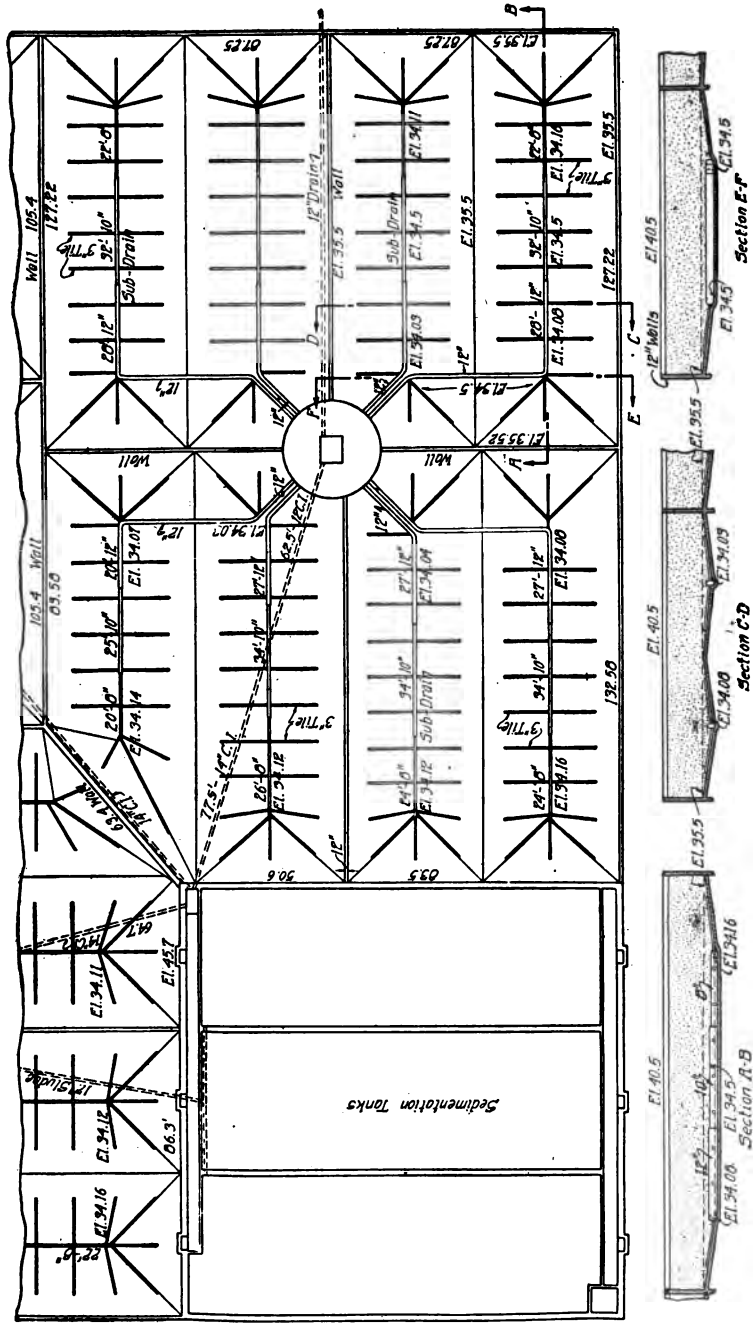


Fig. 15. Plan and Sections of the Contact Beds at Alliance, Ohio

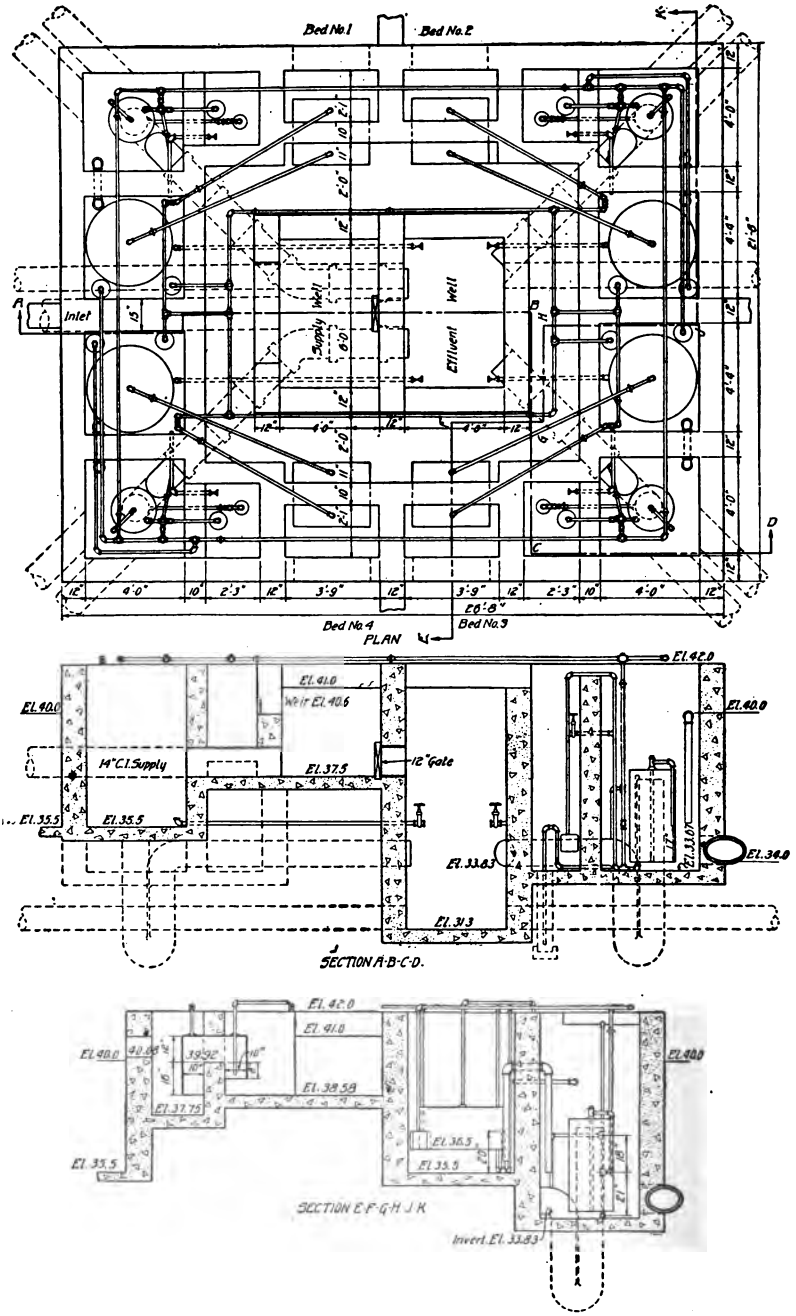


Fig. 16. Plan and Sections of Automatic Control Chamber for Contact Beds at Alliance, Ohio

rises in these compartments which are connected up to the filters, it displaces the air in the bells, gradually compressing it until it is of pressure sufficient to displace the sewage in the connected siphon, so that when one filter is full, it closes itself, opens up the inlet valve to another filter, and then opens up the outlet valve of the filter just filled.

Head Required. Contact filters are well adapted to gravity filtration plants where the loss of head due to the operation of the plant is limited to 6 feet or 8 feet. They are much more expensive in construction than sprinkling filters, which are less

Fig. 17. Automatic Control Chamber for Contact Beds at Alliance, Ohio

likely to clog up and which give equally good results. Sprinkling filters, however, require at least eleven feet of head.

SPRINKLING FILTERS

Use. Sprinkling filters operate on the same principle as contact filters and are used for the same purpose, although the method of application of the clarified sewage is entirely different. They are essentially biological filters depending upon the action of *aërobic* bacteria, and the same method of removing the remaining suspended and organic matter from the sewage is carried out in the sprinkling filters.

Design. Sprinkling filters do not require water-tight concrete compartments and do not have to be subdivided. They can, therefore, be constructed much more cheaply than contact beds. They are built with an effective depth of from 5 feet to 8

Fig. 18. View of Sprinkling Filters in Operation at Polk, Pennsylvania, Disposal Plant

feet and are constructed of broken stone or other material with a dense clear fractured surface of a size ranging from 1 inch to 3 inches. The sewage is applied to the surface every fifteen or twenty minutes by means of troughs, nozzles, or traveling distributors so as to spread uniformly in a fine spray over the entire surface, Fig. 18. It then trickles down through the broken stone, only a few minutes being required for it to pass through the filters. The period of application is usually five minutes. The bottom of the filter is entirely underlaid with tile to assist in aëration, and provision is usually made for ready access to the underdrains and distributors, for frequent inspection and for cleaning if necessary.

Sprinkling filters are operated in America under ordinary conditions with clarified sewage at a rate of two and one-half million

Fig. 19. Danville, Pennsylvania, Sprinkling Filters in Operation at 14 Degrees below Zero

gallons per acre per day. Here the usual method of distributing the sewage on to sprinkling filters is by fixed nozzles connected by piping system to an automatic siphon, or to a motor-driven rotating valve. This siphon or valve is supplied by a dosing tank of capacity sufficient to furnish a five-minute dose to the filter and permit the desired resting period. These tanks are usually built in the form of an inverted cone and are known as tapered tanks, this arrangement being necessary to distribute uniformly the sewage over the area supplied by each fixed nozzle. The flow line in this tank is from 5 feet to 10 feet above the surface of the filter in order to give the pressure necessary for distribution. It is, therefore, essential to have a total head of at least 11 feet for proper operation of sprinkling filters with fixed nozzles.

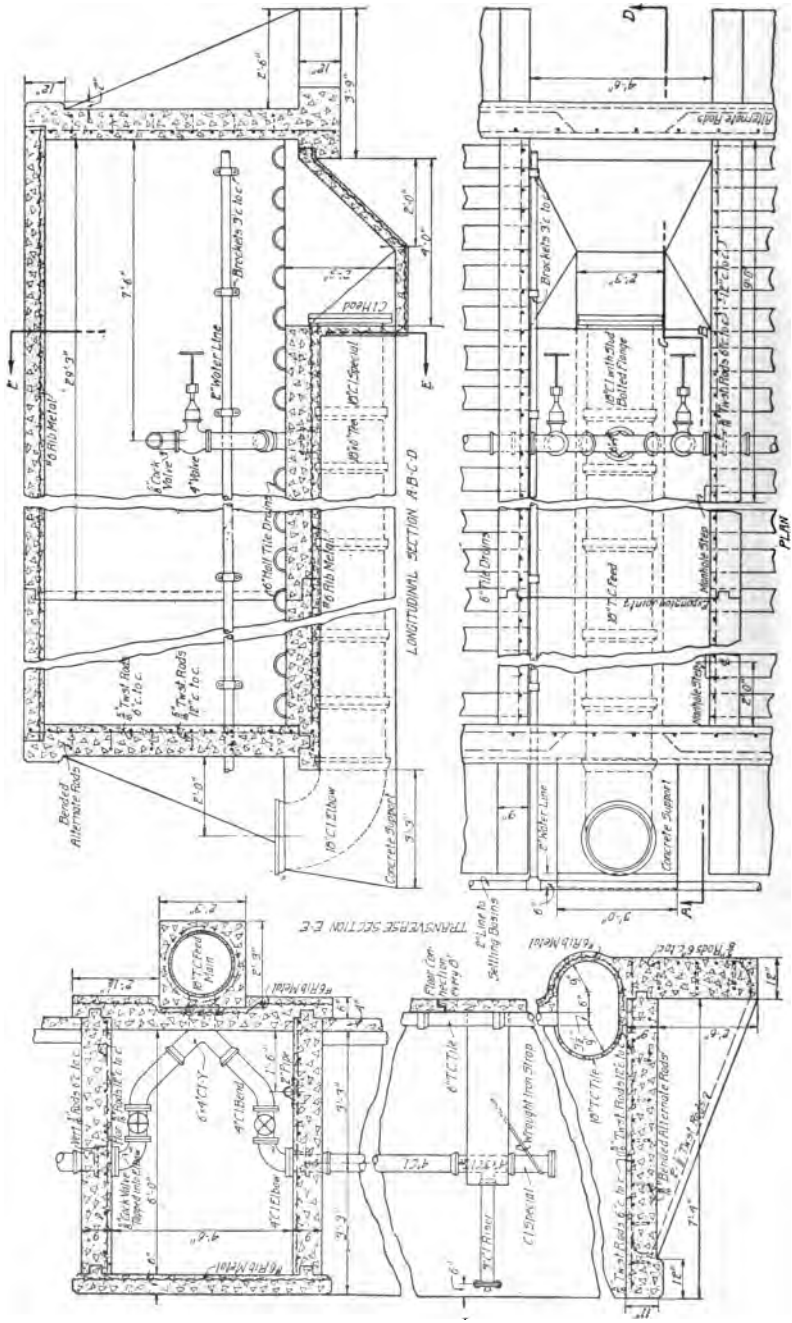


Fig. 20. Typical Details of Sprinkling Filters

Results. The effluent from filters of this type is more putrescible and usually shows a marked reduction in bacterial count over the raw sewage. These filters are self-cleansing, freeing themselves of the accumulated material after it has been mineralized. The effluents are, therefore, not clear, but this suspended material may be removed by settling.

Examples. Figs. 18 and 19 show sprinkling filters in operation for the Polk Plant and the Danville Plant. The Danville filters were being operated at a temperature of fourteen degrees

Fig. 21. Interior of Small Sprinkling Filters, Showing Distribution System

below zero at the time this picture was taken. No trouble has been experienced in America in operating sprinkling filters during cold weather.

Polk Filters. Figs. 20, 21, and 22 show details of the construction of sprinkling filters. It will be noted that all of the filters are operated by automatic siphons supplied by concrete tanks at the outlet ends of the settling tank. These siphon chambers are designed for a capacity sufficient to give an interval of fifteen to twenty-five minutes between doses as may be desired.

To refer in detail to the Polk sprinkling filters, which are typical of American installations, these filters are designed in two units, separated by a concrete gallery in which are located the valving and connections for the distributing line. This gallery is 4 feet wide and 6 feet deep. Under the floor of this gallery there is an 18-inch conduit connected to the siphon chamber at one end of the gallery and adjacent to settling tanks. From this conduit

Fig. 22. Interior of Sprinkling Filter, Showing Underdrains Partly Laid

at intervals of 12 feet there are 6-inch risers which supply the 4-inch distributing lines in the two filters. Each distributing line is controlled by a 4-inch valve. The distributing lines, as will be noted, are constructed of cast iron and are supported every twelve feet by concrete columns. Along these distributing lines are located the riser pipes to the nozzles, which are so spaced as to place the nozzles 14 feet center to center. The distributing lines can be

cleaned readily by removing the flanged elbows in the operating gallery. The nozzles consist of a brass throat $\frac{9}{16}$ inch in diameter, above which is set a brass cone, as shown in Fig. 23. The sewage when discharged through the throat of the nozzle, strikes this cone and is sprayed over the surface of the filter as indicated in the illustration. The underdrains for these filters consist of 6-inch split tile laid on a concrete slab and sloping from the control gallery to a cross-drain located at the opposite side of each filter. These underdrains are spaced 12 inches center to center and extend through the gallery wall to the interior so that they can be flushed out with a hose from the gallery and can also be ventilated through same. The filtering material consists of a hard sandstone ranging in size from 4 inches to 1 inch with an effective depth of 6 feet. These filters are constructed with concrete walls around each unit. In many installations, however, a dry rubble wall is used for the outside walls and in some cases where the filters are located above ground, the filtering material itself is carefully laid up to serve as a wall for the filter.

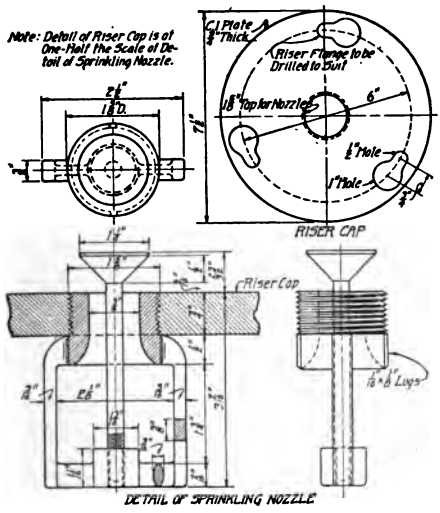


Fig. 23. Details of Sprinkling Filter Nozzle

SAND FILTERS

Use. Sand filters represent an artificial type of broad irrigation in two respects: (1) they consist of specially prepared filters of coarse sand, well underdrained and provided with distributing troughs for applying the sewage uniformly to the surface; and (2) the results obtained are from the action of *aërobic* bacteria on the organic and suspended matter that is retained in the sand. They may be used to treat raw sewage or clarified sewage or as a final treatment after biological filters. Sand filters will give a

much higher degree of efficiency than the two types of biological filters previously described, and the effluent from sand filters should not only show a high degree of efficiency in the removal of organic matter, but also a marked reduction in the bacteria.

Design. Sand filters require an area of 1½ acres per 1000 people for raw sewage; ½ to 1 acre per 1000 people for clarified sewage; and ⅛ to ¼ acre per 1000 people as a final for biological filters. They must be operated intermittently to permit a thorough aëration of the sand between the treatment periods. These filters are usually constructed of a depth of from 2 feet to 4 feet and are underlaid with underdrains in a manner similar to the contact filters. The sewage is usually applied to a depth of 2 inches over the entire surface of the filter at intervals of not less than 8 hours apart and at longer intervals if possible. The sewage is usually distributed by a series of wooden troughs extending over the surface of the filter from the automatic control apparatus and provided at frequent intervals with gates or notches for spreading the sewage over the surface. In cold climates a ridge and furrow method of distribution must be used to prevent freezing.

Sand filters are usually installed in groups, arranged and controlled in a manner similar to that described for contact beds, with the exception that the sewage is applied to the trough system on the surface, there being no control to the outlet drains.

Alliance Filters. Fig. 24 shows the arrangement of sand filters which are used to filter the effluent from the contact beds at Alliance, Ohio. Sewage is allowed to run onto one bed at a time from a common collector connected with the contact beds. After several hours, the flow is shut off by hand and turned onto the next bed. These beds, with a uniform depth of three feet, have a total area of four acres and are therefore designed to treat the contact bed effluent at a rate of 500,000 gallons per acre per day. Having been distributed over the surface by wooden troughs, the sewage is collected by a system of terra cotta tile drains as shown. A central control tank is also frequently installed of a capacity sufficient to dose out enough sewage to cover the surface of the filter to a depth of 2 inches and to store enough to give the proper periods of intermission, as above outlined.

Sand filters in most locations in America call for an installation

expensive in comparison with that of contact beds or sprinkling filters supplemented by disinfection, and they are therefore few

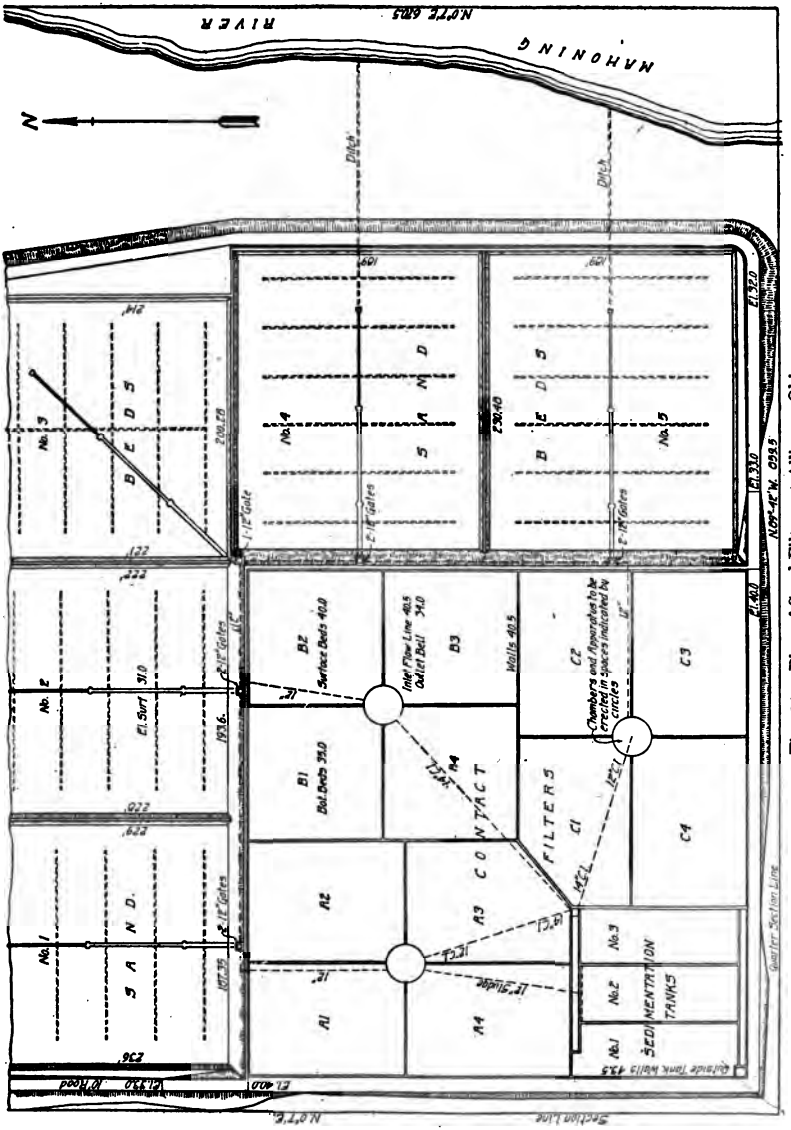


Fig. 24. Plan of Sand Filters at Alliance, Ohio

in number on any scale, outside of the New England district where sandy areas are abundant.

DISINFECTION

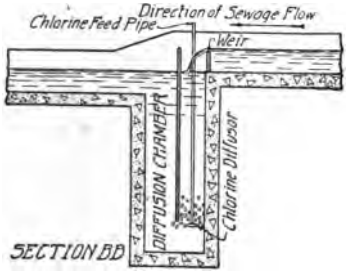
Purpose. Where sewage or the effluent from a disposal plant is discharged into a stream above a water supply, it is necessary to remove the danger of transmitting water-borne diseases. This is accomplished by disinfection or the removal of pathogenic bacteria as indicated by the absence of *b. coli.* Sterilization consists in the removal of all bacteria. As the pathogenic bacteria are weaker than the rest of the sewage bacteria, they are removed more easily and at less expense. It is found also that in sterilizing sewage, the organic matter is unaffected and upon its being discharged into a stream, new growths of bacteria will quickly develop from those already in the stream. Sterilization is, therefore, usually not attempted.

Method. Disinfection may be accomplished by the application of a definite amount of hypochloride of lime in solution, or chlorine gas, or electrolytic action. Chloride of lime may be purchased commercially at from 1¼ cents to 3 cents per pound depending on the size of containers, with a rated strength of 33 per cent available chlorine. It is then dissolved in a weak solution of water, and this solution is applied to the sewage at a rate of 3 to 4 parts available chlorine per million parts of sewage by weight, or 75 to 100 pounds per million gallons. At this rate, a complete removal of *b. coli* can be obtained and a great reduction in total bacteria. Most of the bacteria are destroyed instantly, but it is necessary to have fifteen or twenty minutes' contact to obtain thorough disinfection. After treatment, the sewage is therefore allowed to flow through a compartment of fifteen or twenty minutes' maximum flow capacity.

The chlorine gas treatment costs about the same as the chloride of lime and is more efficient in that it is more easily controlled. It consists of containers of chlorine gas compressed to a liquid. This liquid is fed by automatic apparatus at the desired rate into the sewage.

The electrolytic treatment is more expensive in operation under ordinary conditions. It consists in passing a current through the sewage between poles which form an electrolyte and give a nascent oxygen treatment to the sewage. In addition to the disinfection, there is a precipitation of a part of the suspended matter.

Fig. 25. General View of Liquid Chlorine Disinfection Plant



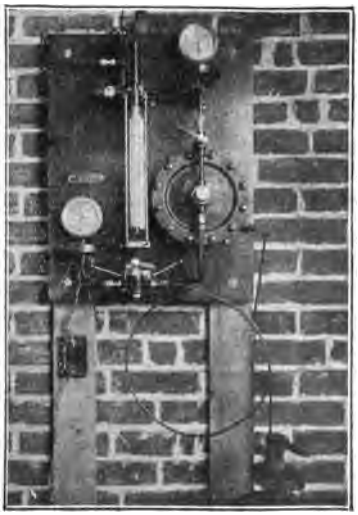
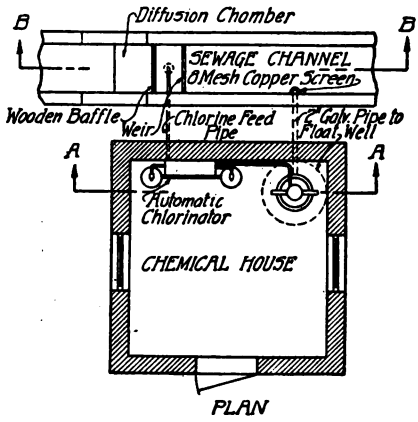


Fig. 26. Automatic Chlorinator



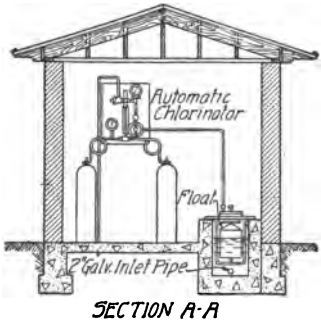


Fig. 27. Plant and Sections of Disinfection Plant

Automatic Appliances. Automatic devices are required for efficient disinfection since it is necessary to apply the solutions at a rate in proportion to the flow of sewage, and as the flow varies hourly. With the use of chloride of lime, this can be accomplished by a float chamber connecting to the sewer and arranged so that the float operates a lever which varies the head on the orifice from the solution box in proportion to the flow of sewage. A diaphragm control from a Venturi meter on the sewer is another method. Liquid chlorine must be fed by automatic apparatus that not only keeps the treatment of the sewage uniform, but also controls the liquid chlorine pressure tank.

Fig. 28. Automatic Control Apparatus for Liquid Chlorine

Chlorine Gas Installation. Figs. 25 to 27 show a typical installation of a liquid-chlorine plant for treating the effluent from a sewage disposal plant. This plant consists of a small brick building, Fig. 25, in which the automatic apparatus is located and a re-settling basin of reinforced concrete which permits the sewage to come in contact with the liquid chlorine for a minimum period of fifteen minutes before being discharged into the stream. The automatic apparatus, Fig. 26, is controlled by a float chamber, Fig. 27, located in one corner of the pump room and directly connected to the sewer outside the building at a point on the upstream side of a fixed weir. This float transmits the difference in elevation, due to the varying flow of sewage over the weir, by diaphragms directly to the central control diaphragm. Here the drop in pressure across the chlorine gas constriction in the connecting valve from the chlorine-pressure tanks is kept proportional to the head

on the weir. This gives a proportional flow of chlorine for the varying heads over the weir. The liquid chlorine is then fed to the outfall sewer below the weir and is liberated in a baffled concrete compartment called a "diffusion chamber", section *BB*, so that the chlorine will be thoroughly mixed with the sewage to be treated.

Fig. 28 shows another type of liquid-chlorine apparatus where a different type of control is used. This consists of pressure regulating devices to produce the initial cylinder pressure of the liquid chlorine and to control this pressure through a range sufficient to give the required discharge of gas. On the outlet line, there is attached a low-pressure chlorine gauge calibrated to indicate the rate of flow of chlorine gas. This apparatus can also be used in connection with Venturi meters to supply the chlorine automatically in proportion to the flow of sewage.

Results. Where the chlorine-gas apparatus is used on raw sewage, the results are unreliable if there are large pieces of organic matter in suspension, as the treatment will not destroy the bacteria inside these masses. For treatment of clarified sewage or effluents from disposal works, a uniformly high degree of efficiency can be obtained.

PUMPING

Requirements. Where it is at all possible to eliminate pumping, it should be avoided, as it not only adds a high operating cost, but also is difficult in maintenance. Pumping is, however, a necessity at many disposal works where the outfall sewer is too low to permit of gravity operation or where the plant would otherwise be subjected to flood conditions. It is necessary, too, for many of the modern buildings in our large cities where the deep basements and sub-basements are entirely too low to drain to the sewers.

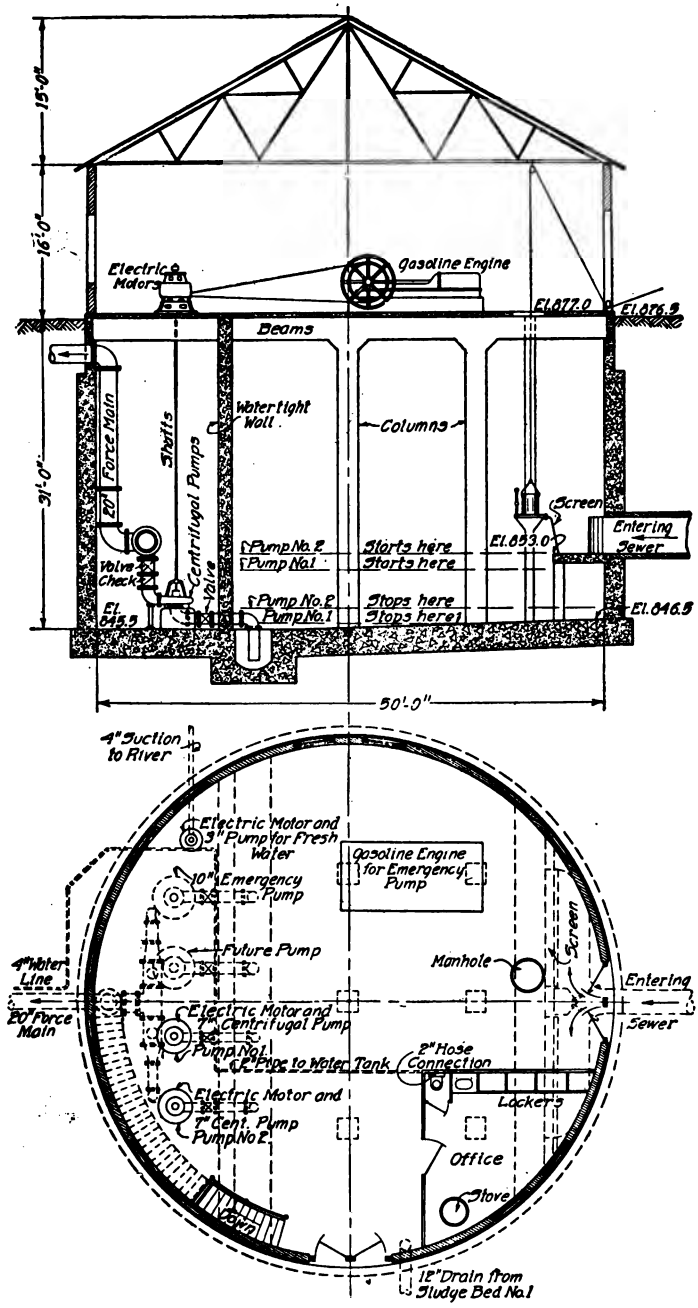
Method. Sewage pumps must be reliable, free from obstructions, and in many cases automatic. Centrifugal pumps with open type impellers, steam or motor driven, are naturally adapted to sewage pumping on account of simplicity, possibility of automatic operation, and their large capacity for low heads. Automatic ejectors operated by compressed air are usually used on small installations.

Design. For stations that are to be automatic, motor-driven centrifugals are well adapted. The pump must be submerged and preferably placed in a compartment separate from the sewage so as to be accessible at all times. Particular attention must be paid to protecting the pumps from injury or clogging from suspended matter in the raw sewage, and for this purpose, screen chambers must be designed and installed as previously outlined under that heading. The motor should be placed on the operating floor above the pump well to prevent trouble from dampness.

The pump well must be of capacity sufficient to permit the sewage to reach the pumps without swirling and also to give some margin for a temporary closing down or changing over of pumps, and, in the case of automatic stations, to permit of proper periods between stopping and starting. A minimum of thirty minutes' storage of the maximum flow should be used. In determining the size of the pump, study must be made of the varying flow of sewage at different hours of the day, and under maximum and minimum conditions; while its capacity must be such that it can take care of the flow of sewage under all conditions and at the same time permit of at least one pumping unit being out of operation. Where there is a possibility of the supply of electric current being interfered with, auxiliary power should be provided.

In the design of larger stations or of stations where the cost of current is not comparable with other fuel, steam-driven or gas-engine-driven installations can be made, but stations of this type must be supplied with operators.

Connellsville Pumping Station. Fig. 29 shows a plan and section of an automatic electric-driven pumping station designed for Connellsville, Pennsylvania. This station consists of a circular pit 50 feet in diameter by 30 feet deep, with the top of the pit carried up to the natural ground level, which is above extreme high-water mark, and with the bottom of the pit 7 feet below the invert of the connecting sewer. The pumping equipment consists of two 7-inch centrifugal pumps run by electric motors and each having a capacity of one and one-half million gallons per twenty-four hours; and one 10-inch auxiliary pump run by a gas engine and having a capacity of three million gallons per twenty-four hours. There is a concrete diaphragm wall separating the pump pit from



PLAN and SECTION of PUMP HOUSE

Fig. 29. Plan and Section of Connellsville Proposed Sewage Pumping Station

the suction pit so that the pump pit will be dry at all times and pumps can be conveniently reached for inspection or repairs. The main suction pit will have an effective capacity of 75,000 gallons or a minimum storage of 30 minutes under maximum conditions. The motors operating the pumps will be located on the reinforced-concrete operating floor above the pit and directly connected to the pumps by vertical steel shafts. Each motor will be automatically controlled by a float located in the pit and connected to the switchboard so that when the sewage rises in the pit to a depth of four feet, one pump starts up. If the flow is greater than the capacity of this pump, the sewage will continue to rise for another foot when the second pump will start up. When the sewage drops in the pit to within two feet of the bottom, the last pump in operation is cut off by the float and when it reaches the bottom, the second pump is placed out of commission. The auxiliary pump is provided to take care of any breakdown in the other machinery and also to provide against a failure of the current supply. A small 3-inch pump similar to the other electric-driven pumps is provided for taking raw water from the river and supplying it for flushing purposes through a force main to the disposal works.

Ejectors. Figs. 30 and 31 show an installation of Shone ejectors and also a sectional detail of one of these ejectors. Ejectors like pumping installations, should be set up in duplicate as indicated in the illustration, so that there will be a spare unit for use in emergency. Ejectors are simple in operation as they have no working parts which can become clogged with suspended matter, and when operated with compressed air, can be located at a considerable distance from the air compressor or air tank.

As will be noted in Fig. 31, these ejectors consist of a closed cast-iron vessel furnished with inlet and outlet connections which are controlled by check valves. Gate valves are also provided, but are only used to disconnect one unit for repairs. On top of the ejector is placed an automatic valve to which is connected the air pipe from the air compressor. This valve controls the admission of the compressed air into the ejector and also the exhaust of displaced air from the ejector. It is operated by the two cast-iron bells hung in reversed positions and linked to each other by a rod through the center of the main compartment as shown. When

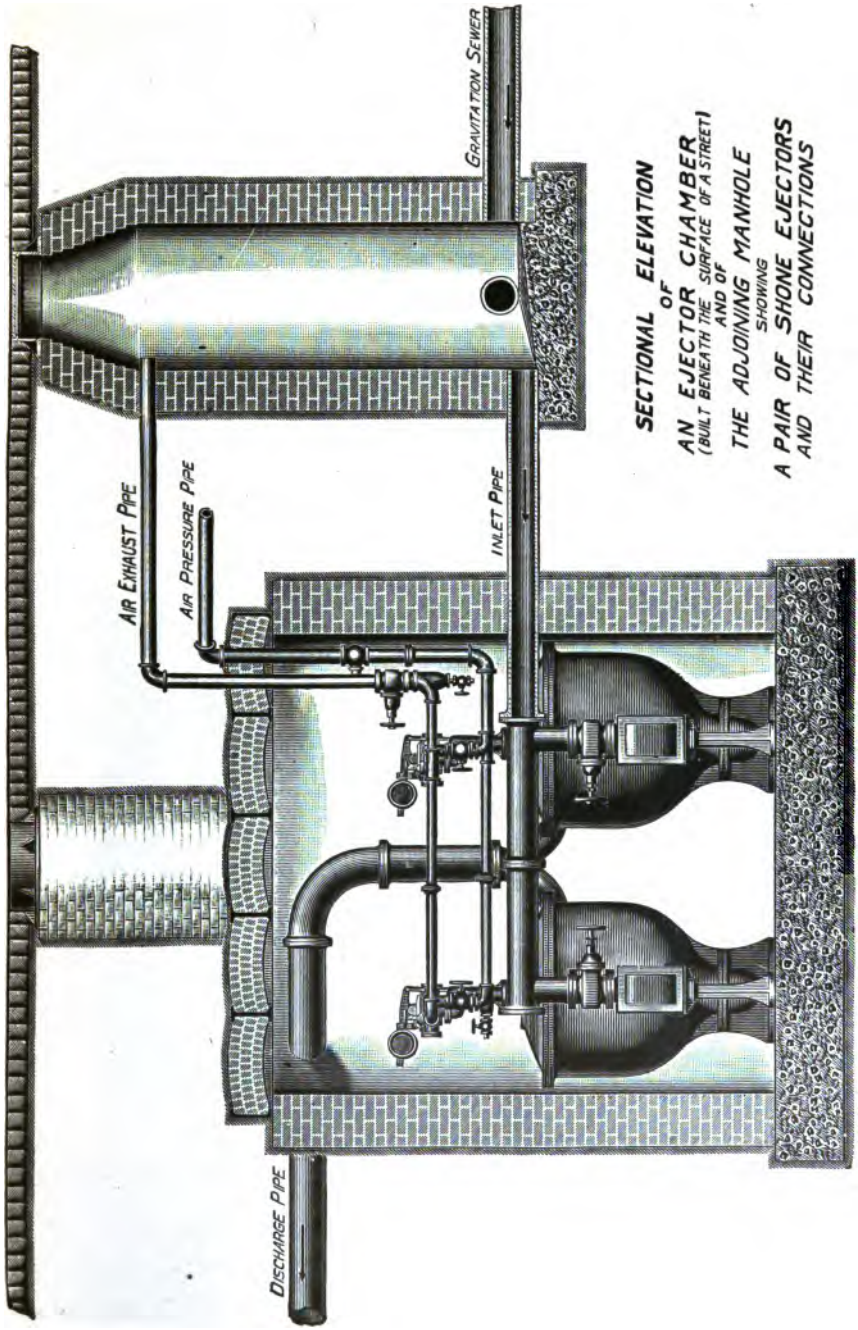


Fig. 30. Typical Installation of Shone Ejectors

the sewage rises in the ejector, the exhaust valve is opened and the air valve is closed, the bells being in the lower position. When it reaches the top of the ejector, it traps air in the upper bell forcing it to rise by buoyancy. The lever connected with the rod from the bells quickly closes the exhaust and opens the compressed-air

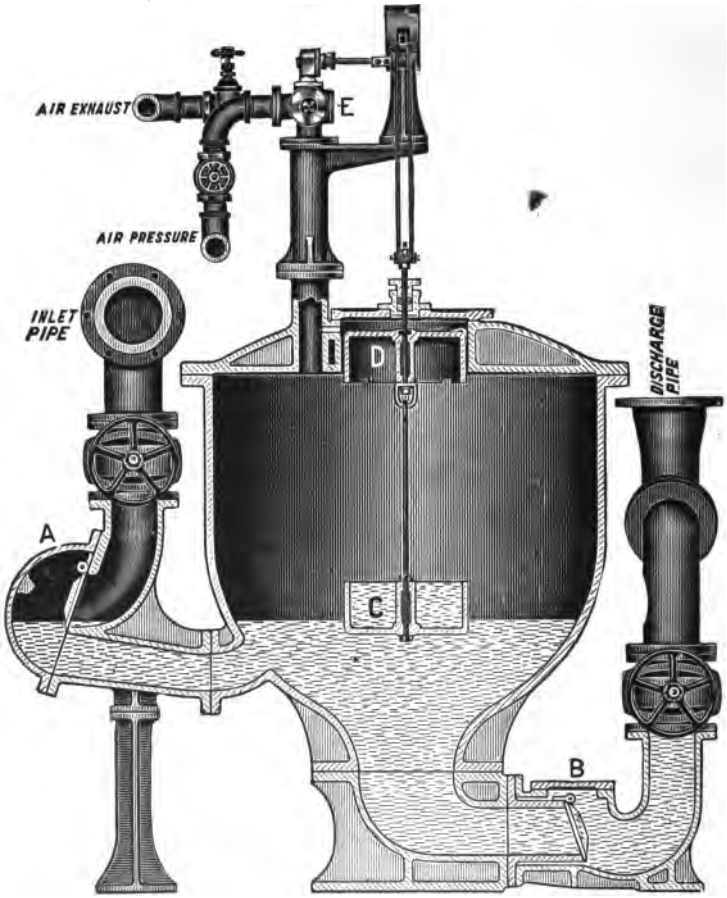


Fig. 31. Detailed Section of Shone Automatic Ejectors

connection and the compressed air immediately forces the sewage from the compartment into the discharge pipe. When the sewage reaches the lower bell, its weight pulls down the control rod, thereby reversing the position of the pressure and exhaust valves and allowing the ejector to start again the process of filling. It requires

very little more air pressure to operate this type of ejector than the head of water against which it must lift.

SUMMARY

Sewage-Disposal Method—Question of Conditions. It will be seen from the outline given of the various methods of sewage disposal and the results that can be obtained, that each case must be studied and worked out as an individual problem. Dilution is feasible under certain conditions, but usually with some treatment such as screening or disinfection, or a partial removal of the suspended matters. Broad irrigation and chemical precipitation, which were once popular, are now installed only under exceptional conditions on account of the high cost of these methods of treatment. A non-putrescible effluent with a high percentage of removal of the organic matter and bacteria can be obtained by broad irrigation, but only a partial removal of it can be obtained by chemical precipitation.

Care of Suspended Matter and Effluent. For the removal of suspended matters, mechanical screens, Imhoff tanks, and septic tanks are generally used. Where there is danger of trouble from odors, screens or Imhoff tanks are preferable. Where it is necessary to produce a non-putrescible effluent, a secondary treatment must be given the effluent from which the suspended matter has been removed, and this is accomplished by biological filters of which the sprinkling filters and contact beds are the types generally used. Sprinkling filters are preferable to contact beds on account of lower cost, but require more head so that in many cases they cannot be considered.

Disinfection of Effluent. The effluent from biological filters is not free from bacteria and where a removal of pathogenic bacteria is required, the effluent must be disinfected. This is generally accomplished by chloride of lime or liquid chlorine. Sand filters will give a much higher degree of efficiency than the coarse-grain biological filters, but on account of high cost are not generally used.

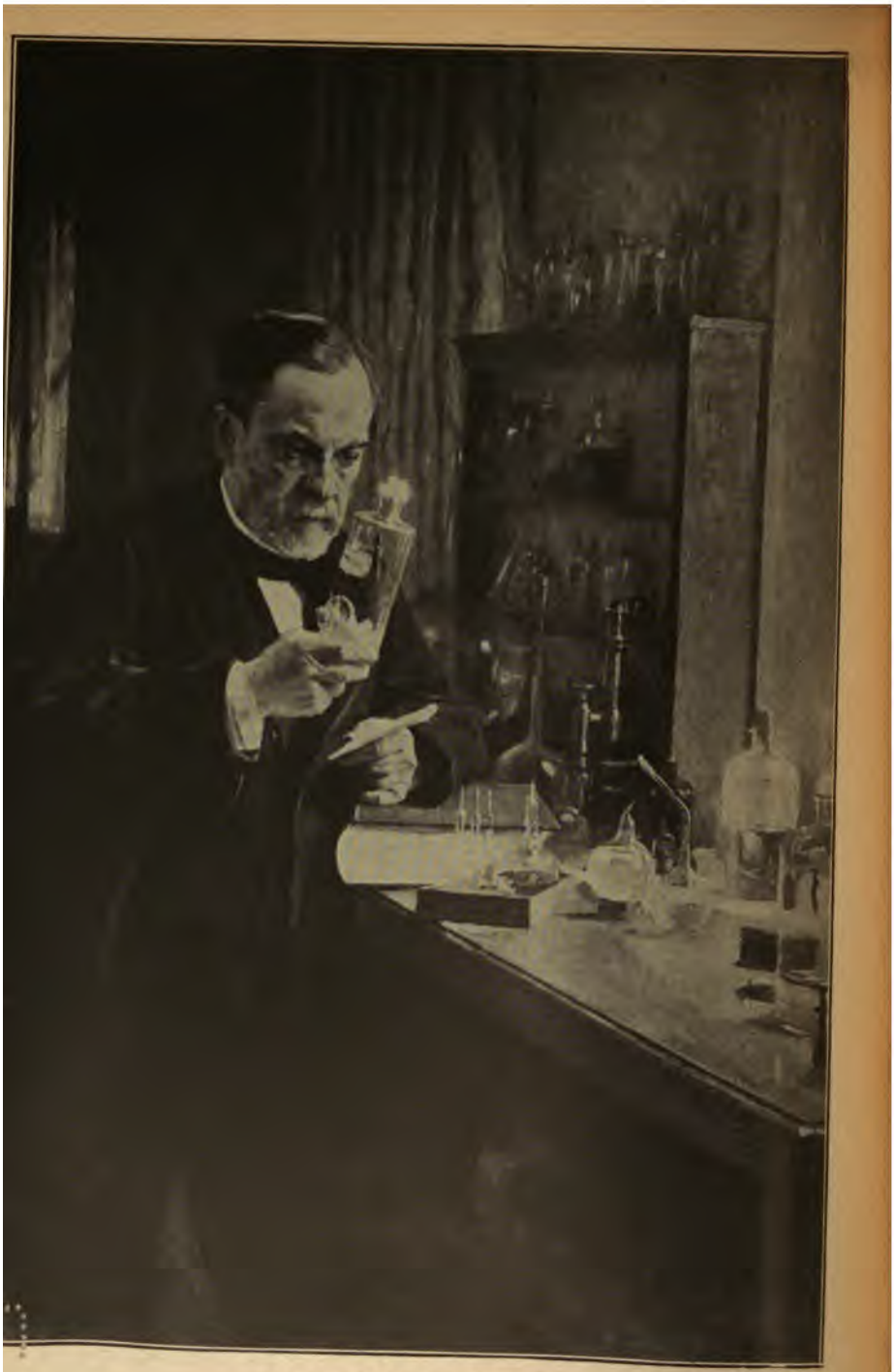
Electrolytic treatment will efficiently disinfect sewage, but on account of cost of treatment, it has not been able to compete with the other methods of disinfection. Experiments are now

being conducted on activated sludge, formed by blowing compressed air through freshly deposited suspended matters. This process appears to liquefy and nitrify the sludge in a very short period of time by accelerating the growth of enormous numbers of small worms in the sludge deposits. These experiments indicate a development of a new method of handling the sludge problem, although on account of the high cost of operating it is doubtful whether it will be as economical as the double-story tank method with separate digestion compartment now so generally and successfully used.

Pumping should be avoided if possible. If it must be used, the apparatus must be arranged to avoid clogging and in most small installations to be automatic. Where compressed air is available, an ejector is the simplest type of pump to use.

Future Conditions. As the population of this country increases and new towns spring up, the necessity for purification of sewage increases and the time is not far off when even our seacoast cities must adopt partial purification. It is, therefore, of vital importance to make the present type of partial treatment now installed, whatever it may be, subject to further development of a higher degree of purification.

Finally, too much emphasis cannot be placed on the importance of a thorough study of conditions, and of development of a comprehensive scheme to embrace not only present circumstances, but future contingencies.



PASTEUR IN HIS LABORATORY

asteur was the First to Develop the Study of Bacteria—the Active Agents in the Spread of ntagious Diseases and in the Contamination of Water Supplies, and the Useful Agents in ewage Disposal.

BACTERIOLOGY AND SANITATION

INTRODUCTION

Ours is an age when the people, even of the poorly educated classes, accept without skepticism or surprise the news of a great scientific discovery, yet it is barely seventy years ago that the world received with almost incredulous astonishment the announcement that "Beer yeast consists of small spherules which have the property of multiplying and are, therefore, a living and not a dead chemical substance; that they further *appear* to belong to the vegetable kingdom and to be in some manner intimately connected with the process of fermentation."

When Latour communicated the above observation on yeast to the Paris Academy of Science, June 12, 1837, the whole scientific world was taken by storm, so great was the novelty, boldness, and originality of the conception that these insignificant particles, heretofore reckoned as of little or no account, should be endowed with functions of such responsibility and importance.

At the time when Latour was sowing the first seeds of this great gospel of fermentation, started curiously enough and almost simultaneously across the Rhine, by Schwaan and Kützing, its greatest subsequent apostle and champion, Louis Pasteur, was only a lad of fifteen, buried in a little town in the provinces of France. Yet some thirty odd years later there was not a country in the whole world where Pasteur's name was not known and associated with these classical investigations in fermentation, in the pursuit of which he spent so many years of his life, and which have proved of such incalculable benefit to the world of commerce as well as science. He cleared away the débris of misconception which had so long concealed from view the vital character of the changes associated with these processes and started the bacterial ball—if it may so be called—rolling with a will,

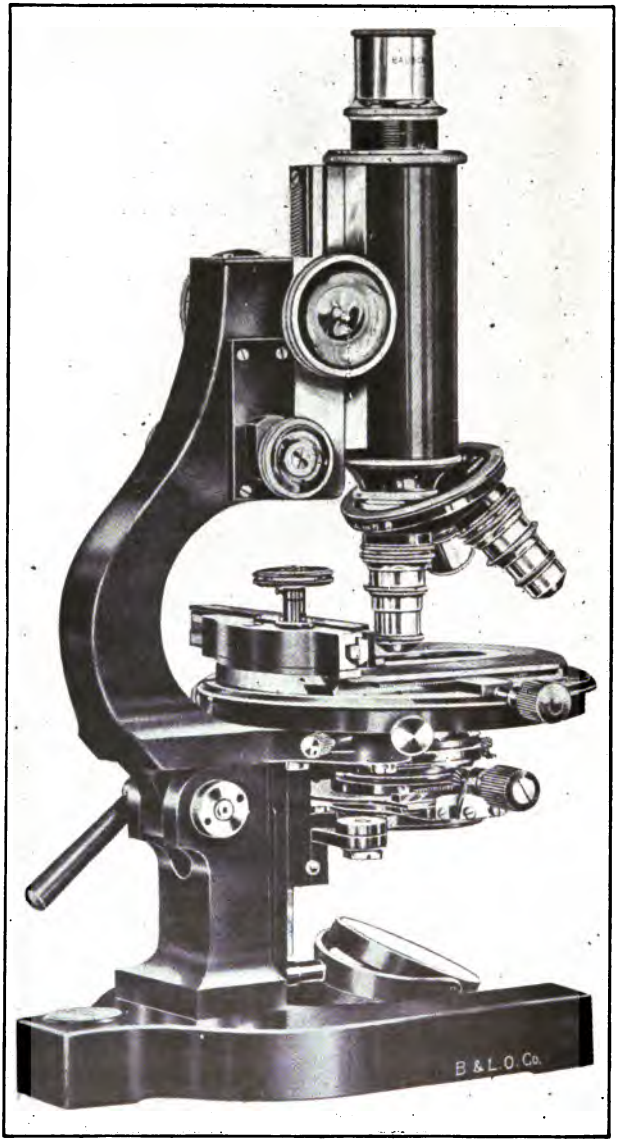


Fig. 1. A Modern Compound Microscope.

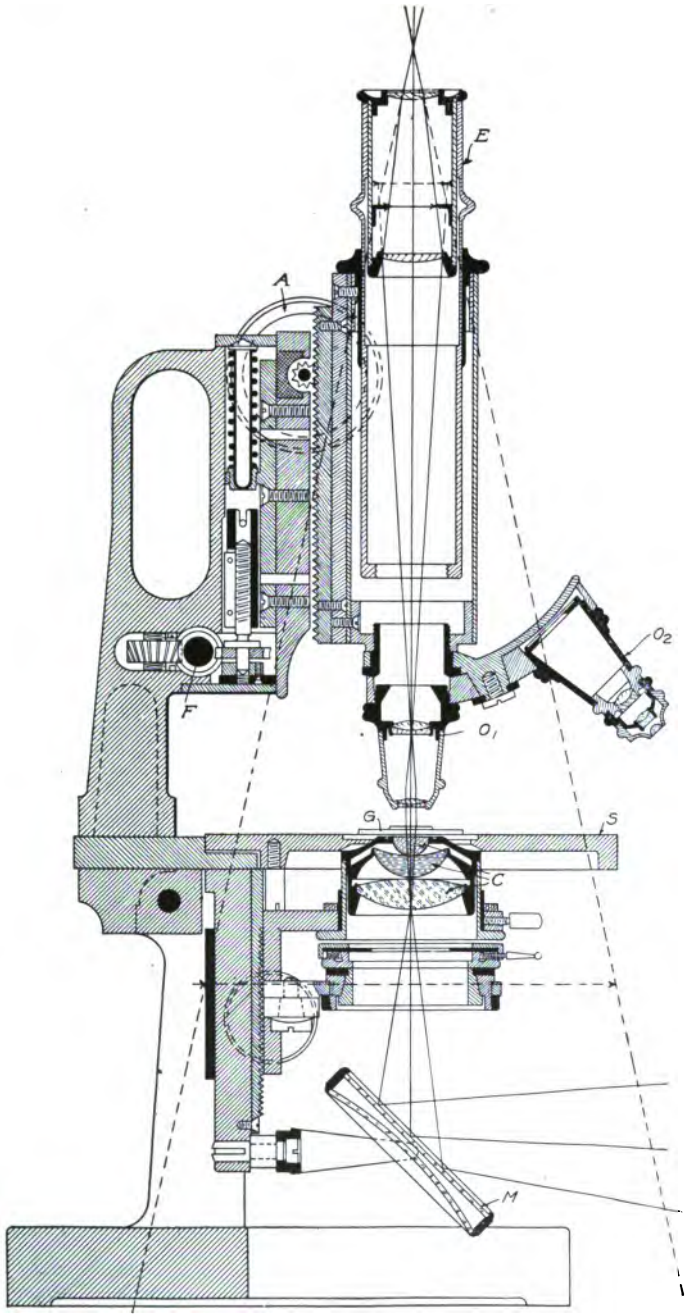


Fig. 2. Section of Compound Microscope, Showing Path of the Light Rays. E, eye piece; O_1 and O_2, achromatic objectives; C, Abbé condenser for concentrating the light; M. mirror; S, stage on which specimens are placed; G, specimen on cover glass for examination; A, coarse adjustment screw for focusing; F, fine adjustment screw.

and information concerning these minute particles of living matter was readily gathered up from all directions.

The recognition so long refused to bacteria was now ungrudgingly given them and it was realized at last that, in the words of M. Duclaux, "Whenever and wherever there is decomposition of organic matter, whether it be the case of a weed or an oak, of a worm or a whale, the work is exclusively performed by infinitely small organisms. They are the important and almost the only agent of universal hygiene; they clear away more quickly than the dogs of Constantinople or the wild beasts of the desert what remains of all that has had life; they protect the living against the dead. In fact, they do more— for if there are still living beings, if, since the hundreds of centuries the world has been inhabited, life continues, it is to them we owe it."

To-day the science of bacteriology has revolutionized our ideas of disease, has robbed it of its horror, and has taught us the laws of right living, obedience to which will effectually prevent the spreading, at least, if not the recurrence, of epidemics of such well-known maladies as cholera, plague, typhoid fever, and smallpox.

HISTORY OF BACTERIOLOGY

The honor of being the first to see bacteria and identify roughly their form undoubtedly belongs to a Dutch lens-maker named Van Leeuwenhoek, who, in the latter part of the seventeenth century, saw through his microscope "Tiny animals which moved about in the most amusing fashion." After nearly a century, the Danish zoölogist, Müller, discovered many structural details, of which his predecessors had been ignorant, and succeeded in describing so faithfully several kinds of bacteria that they can be identified to-day. However, progress was exceedingly slow and, although Ehrenberg (1795-1876) did much important work in classifying and naming some of the principal forms, no great increase in the knowledge of these invisible organisms was recorded.

The Compound Microscope. The reason for the lack of development noted above, which, in the light of subsequent discoveries is perfectly clear to us, was the imperfection of the tools with which these men had to work. Bacteriology, being the study of living things much too small for the naked eye to see, was dependent in its own development upon the improvement of the compound micro-

scope, an instrument which had been invented as early as 1650 but, owing to its imperfect construction, was incapable of furnishing the higher magnifying powers which were necessary to make visible the structure of these minute organisms. Between the period 1815 to 1830, however, the long looked for improvement came and what is known as the *achromatic objective* was invented. This attachment to the microscope, together with improvements in quality and workmanship of the lenses, not only cleared the microscopic field of disturbing colors due to the dispersion of light, thereby making extremely high magnifications possible, but also immensely increased what in lens parlance is known as *definition*, or *detail*. Figs. 1 and 2

Fig. 3. Favus Culture (man). (From *Kolle & Wassermann.*)

Fig. 4. Yeast Ferment. (From *Kolle & Wassermann.*)

show the modern microscope with which magnifications of 3,000 or more diameters are perfectly possible; Leeuwenhoek probably could not have obtained over 100. Almost immediately this device bore fruit in its application to bacteriology. In 1837, an Italian inventor, Bassi, announced that *muscardine*, a contagious disease of silkworms previously not understood, was really due to a parasite. Two years later a still more startling discovery was made by Schoenlein that *favus*, a rather rare disease of the human scalp, was also due to a parasitic fungus growing at the roots of the hair, Fig. 3.

Fermentation a Disease. Reference has already been made to a contribution from the botanists to the effect that the whole process of fermentation was one of growth of microscopic fungi, Figs. 4 and 5. This latter theory of Latour was not accepted without a struggle

and the powerful opposition of Liebig retarded its acceptance for some time; but it was finally made clear by the work of Pasteur, between 1857 and 1863 that live *yeast* is the real *ferment* of the alcoholic fermentation. It could hardly fail to occur to any thoughtful person possessed of sufficient knowledge of the facts, that if this theory were true for certain diseases of *wine* and *beer* it might well be true for certain diseases of *animals* because of the great similarity in the steps by which the diseases progress in their respective surroundings. As an illustration it might be well to take the fermentation of apple

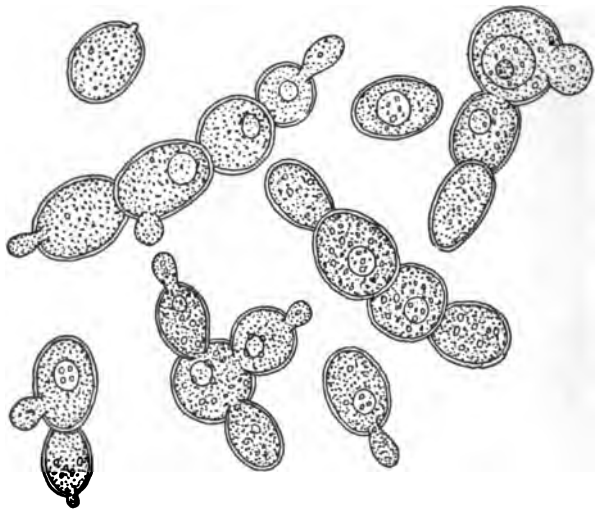


Fig. 5. A Yeast Garden.

juice, or cider, and smallpox. To begin with the apple, its skin protects the flesh of the apple from contamination by the air. On this being removed, however, and the juice pressed out, it is at once exposed to air, to dust, to the press and the sides of the vessel which contains it. At first the juice is sweet and unfermented but after a time the well-known change takes place during which the cider becomes, as is said, *hard.* This process is called *working* or the active fermentation of the cider, and is accompanied by a slight rise in temperature. It is also well known that gas is given off by the cider and the sugar is replaced by alcohol; for this reason the whole process is called *alcoholic fermentation.* This fermentation is not indefinitely prolonged but after a certain time all action ceases and the liquid

assumes a permanent state. Since the work of Louis Pasteur, it is known that what really happened during this process was first, the seeding of the apple juice by wild yeast; second, the slow growth during a period of quiet; third, its active growth and working during the time of greatest fermentation; and fourth, the gradual disappearance of all activity.

To turn to the case of smallpox the process is as follows: A patient who is peculiarly susceptible must be exposed to the disease either by contact with a person already infected, or by clothing, letters, or food which have been handled by such a person. After such an exposure there is a period during which no change takes place, but soon the disease begins to show itself by the appearance of certain symptoms which have become well known to physicians. A little later headache and other troubles appear and the patient becomes seriously ill. A rise of temperature, or fever, is discovered, and eruption and other marks of smallpox appear. This process continues until the crisis is reached, when if death does not supervene, recovery slowly ensues, the patient gradually becoming free from the disease. The patient who recovers is now *immune* from further recurrence of this malady. In other words, just as the cider is susceptible only once to alcoholic fermentation so the smallpox patient is incapable of a second attack of the disease. A study of the progress in these two illustrations will show the striking similarity.

Pasteur and the Silkworm Disease. Pasteur who had so largely contributed to the understanding of this microscopic development in the case of yeasts, was destined to show the accuracy of the parallel between fermentation and disease, which has just been given, in a very startling way. As has been said, his investigations were up to 1863 confined to the study of beer and wine fermentation. In 1865 he responded to an urgent call from the French government to study the famous *silkworm disease.* Inasmuch as the successful solution of this disease was a great factor in establishing bacteriology as a true science, the admirable report of Pasteur's son-in-law, M. V. Radot*, is given in brief, as follows:

"The life of the population of certain departments in the South of France hangs on the existence of silkworms. Fig. 6. In each

*Reprint from "Louis Pasteur: His Life and Labors," by permission of D. Appleton and Company.

house there is nothing to be seen but hurdles, over which the worms crawl. They are placed even in the kitchens, and often in well-to-do families they occupy the best rooms. In the largest cultivations, regular stages of these hurdles are raised one above the other, in immense sheds, under roofs of disjointed tiles, where thousands and thousands of silkworms crawl upon the litters, which they have the instinct never to leave. Great or small, the silkworm-rearing establishments exist everywhere. When people accost each other, instead of saying, 'How are you?' they say 'How are the silkworms?' In the night they get up to feed them or to keep up around them a suitable temperature. And then what anxiety is felt at the least change of weather! Will not the mulberry leaves be wet? Will the worms digest well? Digestion is a matter of great importance to the health of the worms, which do nothing all their lives but eat! Their appetites become especially insatiable during the last days of rearing. All the world is then astir, day and night. Sacks of leaves are incessantly brought in and spread out on the litters. Fig. 7. Sometimes the noise of the worms munching these leaves resembles that of rain falling upon thick bushes. With what impatience is the moment waited for when the worms arrive at the last moulting! Their bodies swollen with silk, they mount upon the brambles prepared for them, where

Fig. 6. The Silkworm in Various Stages of Development, its Cocoons and the Finished Silk.

they shut themselves up in their golden prisons and become chrysalides. Fig. 8. What days of rejoicing are those in which the cocoons are gathered; when, to use the words of Olivier de Serres, the silk harvest is garnered in! . . .

"In the epidemic which ravaged the silkworm nurseries in 1849, the symptoms were numerous and changeable. Sometimes the disease exhibited itself immediately. Many of the eggs were sterile, or the worms died during the first days of their existence. Often the hatching was excellent, and the worms arrived at the first moulting, but that moulting was a failure. A great number of the worms

Fig. 7. Mulberry Trees and the Leaf Pickers.

taking little nourishment at each repast, remained smaller than the others, having a rather shining appearance and a blackish tint. Instead of all the worms going through the phases of this first moulting together, as is usually the case in a batch of silkworms, they began to present a marked inequality, which displayed itself more and more at each successive moulting. Instead of the worms swarming on the tables, as if their number was uniformly augmenting, empty spaces were everywhere seen; every morning corpses were collected on the litters.

"Sometimes the disease manifested itself under still more painful circumstances. The batch would progress favorably to the third,

and even to the fourth moulting, the uniform size and the health of the worms leaving nothing to be desired; but after the fourth moulting, the alarm of the husbandman began. The worms did not turn

Fig. 8. Silkworms Feeding upon the Leaves of the Mulberry Tree, Their Favorite Food.

white, they retained a rusty tint, their appetite diminished, they even turned away from the leaves which were offered to them. Spots appeared on their bodies, black bruises irregularly scattered over

the head, the rings, the false feet, and the spur. Here and there dead worms were to be seen. On lifting the litter, numbers of corpses would be found. Every batch attacked was a lost batch. In 1850 and 1851 there were renewed failures. Some cultivators attributed these accidents to bad eggs, and got their supplies from abroad.

"At first everything went as well as could be wished. The year 1853, in which many of these eggs were reared in France, was one of the most productive of this century. As many as twenty-six millions of kilogrammes (about 28,500 tons) of cocoons were collected, which produced a revenue of 130,000,000 francs. But the year following, when the eggs produced by the moths of these fine crops of foreign origin were tried, a singular degeneracy was immediately recognized. The eggs were of no more value than the French eggs. It was, in fact, a struggle with an epidemic. How was it to be arrested? Would it be always necessary to have recourse to foreign seed? And what if the epidemic spread into Italy, Spain, and the other silk-cultivating countries?

"The thing dreaded came to pass. The plague spread; Spain and Italy were smitten. It became necessary to seek for eggs in the Islands of the Archipelago, in Greece, or in Turkey. These eggs, at first very good, became infected in their turn in their native country; the epidemic had spread even to that distance. The eggs were then procured from Syria and the provinces of the Caucasus. The plague followed the trade in the eggs. In 1864, all the cultivations, from whatever corner of Europe they came, were either diseased or suspected of being so. In the extreme East, Japan alone still remained healthy.

"Agricultural societies, governments, all the world, were preoccupied with this scourge and its invading march. It was said to be some malady like cholera which attacked the silkworms. Hundreds of pamphlets were published each year. The most foolish remedies were proposed, as quite infallible—from flowers of sulphur, cinders, and soot spread over the worms, or over the leaves of the mulberry, to gaseous fumigations of chlorine, of tar, and of sulphurous acid. Wine, rum, absinthe, were prescribed for the worms, and after the absinthe it was advised to try creosote and nitrate of silver. In 1863 the Minister of Agriculture signed an agreement with an Italian who had offered for purchase a process destined to combat

the disease of the silkworms, by which he, the Minister, engaged himself, in case the efficacy of the remedy was established, to pay 500,000 francs as an indemnity to the Italian silk cultivator. Experiments were instituted in twelve departments, but without any favorable result. In 1865, the weight of the cocoons had fallen to four million kilogrammes. This entailed a loss of 100,000,000 francs.

"The Senate was assailed by a despairing petition signed by thirty-six hundred mayors, municipal councillors, and capitalists of the silk-cultivating departments. The great scientific authority of M. Dumas, his knowledge of silk husbandry, his sympathy for one of the departments most severely smitten, the Gard, his own native place, all contributed to cause him to be nominated *Reporter of the Commission.* While drawing up his report, the idea occurred to him of trying to persuade Pasteur to undertake researches as to the best means of combating the epidemic.

"Pasteur at first declined this offer. It was at the moment when the results of his investigations on organized ferments opened to him a wide career; it was at the time when, as an application of his latest studies, he had just recognized the true theory of the manufacture of vinegar, and had discovered the cause of the diseases of wines; it was, in short, at the moment when, after having thrown light upon the question of spontaneous generation, the infinitely little appeared infinitely great. He saw living ferments present everywhere, whether as agents of decomposition employed to render back to the atmosphere all that had lived, or as direct authors of contagious diseases. And now it was proposed to him to quit this path, where his footing was sure, which offered him an unlimited horizon in all directions, to enter on an unknown road, perhaps without an outlet. Might he not expose himself to the loss of months, perhaps of years, in barren efforts?

"M. Dumas insisted. 'I attach,' said he to his old pupil, now become his colleague and his friend, 'an extreme value to your fixing your attention upon the question which interests my poor country. Its misery is beyond anything that you can imagine.'

" 'But consider,' said Pasteur, 'that I have never handled a silkworm.'

" 'So much the better,' replied M. Dumas. 'If you know nothing about the subject, you will have no other ideas than those which come to you from your own observations.'

"Pasteur allowed himself to be persuaded . . . and on June 6, 1865, started for Alais. The emotion he felt on the actual spot where the plague raged in all its force, in the presence of a problem requiring solution, caused him at once to forget the sacrifices he had made in quitting his laboratory at the École Normale. He determined not to return to Paris until he had exhausted all the subjects requiring study, and had triumphed over the plague.

"One of the most recent and the most comprehensive memoirs upon the terrible epidemic had been presented to the Academy of Sciences by M. de Quatrefages. One paragraph of this paper had forcibly struck Pasteur. M. de Quatrefages related that some Italian naturalists . . . had discovered in the worms and moths of the silkworm minute corpuscles visible only with the microscope. . . . This instrument had already rendered such services to Pasteur in his delicate experiments on ferments that he was fascinated by the thought of resuming it again as an instrument of research. . . .

"In a few hours after his arrival he had already proved the presence of corpuscles in certain worms, and was able to show them to the President and several members of the Agricultural Committee, who had never seen them. . . .

"It was necessary to know if there existed the relation of cause and effect between the corpuscles and the disease. This was the great point to be elucidated. . . .

"One of the first cares of Pasteur was to settle the question as to the contagion of the disease. Many hypotheses had been formed regarding this contagion, but few experiments had been made, and none of them were decisive. Opinions, also, were very much divided. . .

"But whatever the divergences of opinion might be, every one, at all events, believed in the existence of a poisonous medium rendered epidemic by some occult influence. Pasteur soon succeeded, by accurate experiments, in proving absolutely that the evil was contagious. . . . All the disasters that were known to have happened in the silkworm nurseries, their extent, and their varied forms were faithfully reproduced. Pasteur created at will any required manifestation of the disease. . . .

"For five years Pasteur returned annually for some months to Alais. The little house nestling among the trees, called *Pont-Guisket*, became at the time his habitation and his silkworm nursery. . . .

"All of the obscurity which enveloped the origin of the diseases of silkworms had now been dispelled. Pasteur had arrived at such accurate knowledge both of the causes of the evil and their different manifestations that he was able to produce at will either of the two important characteristic diseases. He could so regulate the intensity of the disease as to cause it to appear on a given day, almost at a given hour . . . to triumph over the disease called *pébrine* which was so threatening, Pasteur devised a series of observations as simple as they were ingenious . . . this process of securing sound eggs is now universally adopted. . . .

Fig. 9. Examining a Drop of Liquid to Prove the Presence of Disease Germs.

"But if Pasteur brought back wealth to ruined countries, if he had returned to Paris happy in the victory he had earned, he had also undergone such fatigues and had so overdrawn himself in the use of the microscope while absorbed in his daily and varied experiments, that in October, 1868, he was struck with paralysis of one side. Seeing, as he thought, death approaching, he dictated to his wife a last note on the studies which he had so much at heart. This note was communicated to the Academy of Science eight days after this terrible trial.

"A soul like his possessing so great a mastery over the body ended by triumphing over the affliction. Paralyzed on the left side, Pasteur never recovered the use of his limbs, and to this day (1884), sixteen years after the attack, he limps like a wounded man."

Antiseptic Surgery. When the news of Pasteur's discovery reached London, Lord Lister, already an eminent surgeon of Edinburgh, became convinced that the many diseases of wounds which so often result seriously to the patient, were infections and if so must be preventable by proper precautions. Accordingly, he set to work to develop methods along the lines suggested by these discoveries, and by the use of antiseptic dressings, sprays, and sterilized instruments, he was enabled to bring about such a change in surgical methods that these precautions have become the standard methods in surgery since that time. Operations formerly dreaded are now done with perfect assurance and constant success. Operating rooms and hospitals are built with the one idea of exclusion or control of the micro-organisms which are the principal enemies of the patient and the surgeon.

Liquid Cultures. The great value of Pasteur's work, aside from the immediate theoretical results which he obtained, lay in his establishment of the method of growing the bacteria which he was studying and his emphasis of the importance of having these cultures pure. He was, it is true, compelled to use what is known as *liquid* cultivation, that is, the use of a liquid food such as beef broth, on which the bacteria could feed and multiply. Nevertheless, by a long process, he was able to obtain cultures which were fairly pure. Pasteur, therefore, has earned the right to be called the *founder* of bacteriology. It remained, however, for Robert Koch to establish bacteriology as a science; and it is to this noted scientist that the tremendous development in bacteriology during the last twenty-five years is due.

Fig. 10. Anthrax Bacilli in Spleen. (From *Kolle & Wassermann.*)

Koch's first contribution was the positive proof that the disease of cattle and sheep and horses, called *anthrax*, was bacterial in its nature, and also that the bacteria are the *cause* and not the *consequence* of the disease itself, a point which up to this time had been very much in doubt. On

Robert Koch, Who Made Bacteriology a Science.

examining the bodies of cattle dead of anthrax, Koch found, by microscopic examination, Fig. 9, small rods or sticks, Fig. 10, in the blood and other organs. He transferred a small amount of blood or other tissue, charged with these mysterious rods, to a comparatively large portion of the liquid which constitutes the aqueous humor of the ox's eye. This latter was to be the medium upon which the bacteria were to grow. After a few days or even hours the rods had multiplied enormously, while the tissue which was carried over with them was not increased in the least. By successive transfers of this infected portion of the medium to other

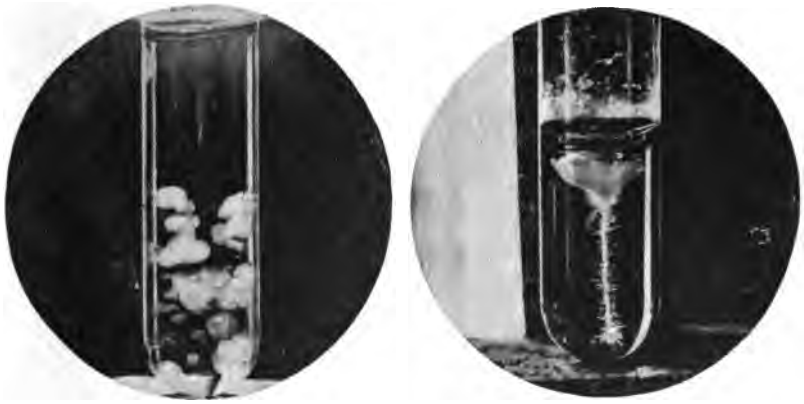


Fig. 11. Typical Solid Cultures.
(From *Gunther.*)

portions of uninfected liquid, Koch was at last able to obtain what would be called a *pure* culture, in which none but living organisms remain and, in fact, in which probably none of the parent organisms existed. Koch reasoned that, if these bacilli were the active agents in the production of the disease of anthrax, and could be placed in the system of a perfectly healthy animal, they would induce an attack of the disease in this new subject. He, therefore, proceeded to inoculate healthy animals with his pure cultures with the result that they promptly manifested symptoms of the disease and died.

Robert Koch and Solid Cultures. This result gave to the study of bacteriology a tremendous stimulus and from 1875, the date of Koch's discovery, until 1881, the progress was brilliant if slow. At the latter date Koch made another discovery which hastened further development most wonderfully. The difficulty with the liquid

cultures, aside from the skill necessary to obtain by repeated transfer of the infected material a comparatively pure culture, has been that the bacteria as they developed could move from one part of the liquid to another and gather in groups or colonies. As a consequence, if different varieties of bacteria were present, their colonies would soon

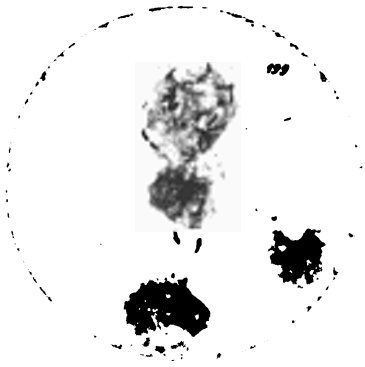


Fig. 12. Human Tuberculosis Bacilli (from lung).
(From *Kolle & Wassermann.*)

Fig. 13. Asiatic Cholera Colony.
(From *Kolle & Wassermann.*)

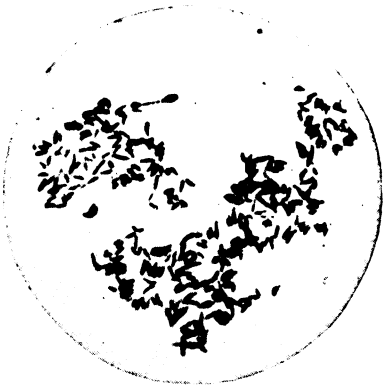


Fig. 14. Diphtheria Bacilli.
(From *Gunther.*)

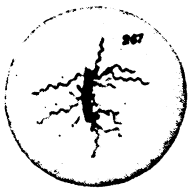


Fig. 15. Typhoid Bacillus (with flagella).
(From *Kolle & Wassermann.*)

become mixed and any particular variety could not be separated. In 1881, Koch hit upon a plan of using *solid* cultures, Fig. 11. By thickening the beef broth or other liquid medium while hot with gelatine or agar, the medium on cooling became a soft moist jelly capable of being melted with a gentle heat and solidifying at room temperature. It will be apparent on a moment's thought that this method would simplify the growing of proper cultures immensely, as the medium would become solid before the bacteria had started

their active growth. Each organism would then be surrounded by its own food, which was at the same time its house, in which it could multiply, but without being able to scatter its progeny to other parts of the medium. After a certain period of growth these colonies would be visible to the naked eye in a tube containing such a culture and at any time a portion of the medium could be removed and the bacteria studied under the microscope. From the date of this discovery bacteriology as a science developed by leaps and bounds. One year after his method of *solid* cultures was devised, Koch announced the discovery of the micro-organism of tuberculosis, Fig. 12. In the following year he added to the list the bacillus of Asiatic cholera, a colony of which is shown in Fig. 13 (see also Fig. 36), and the following two years witnessed the discovery of a number of important bacteria including the diphtheria bacillus by Klebs, Fig. 14; the tetanus or lock-jaw organism by Nicolaier; and a more definite knowledge through Gaffky of the bacillus of typhoid fever, Fig. 15, which had been discovered in 1880, by Eberth under the old method of liquid cultures.

To-day, scattered throughout the civilized world, are bacteriological laboratories, filled with the necessary apparatus and manned by a corps of skilled research men and technical assistants who are searching for further knowledge in regard to the already known organisms and the discovery of the few which still resist their painstaking search. Every up-to-date medical man knows his bacteriology and can by its help detect each of the well-known diseases which used to be such a menace to human life, can watch its progress by means of these analyses, and in a great number of cases bring about a cure. Surgeons and hospital experts have developed antiseptic surgery to such a degree that infections from operations have been reduced to cases of only the grossest carelessness. Every civilized nation is making large appropriations for work along bacteriological and sanitary lines, the benefits from which have shown themselves, for example, in the lack of the diseases characteristic of military camps and battlefields during times of war. The Japanese operations during the recent war with Russia, and the tremendous improvements in sanitary conditions in Havana and Panama, all contribute their testimony to the efficacy of the methods evolved through the aid of this wonderful science.

CLASSIFICATION OF BACTERIAL FORMS

It would be neither possible nor desirable in this short sketch to give any details regarding the structure or mode of development of bacterial forms. The number and variety are so great that their classification resembles in its complexity that of our visible forms in the vegetable kingdom and would lead into discussions not pertinent to the subject of sanitation. However, it is perhaps desirable to gain a general view of the characteristics which are made use of by the bacteriologist in keeping track of his very large and constantly increasing family. When classed according to form, they drop with greater or less facility into three groups known as the *rod* form or *bacillus*, the *ball* form or *coccus*, and the *spiral* form or *spirillum*, as illustrated by Figs. 16, 17, and 18. This

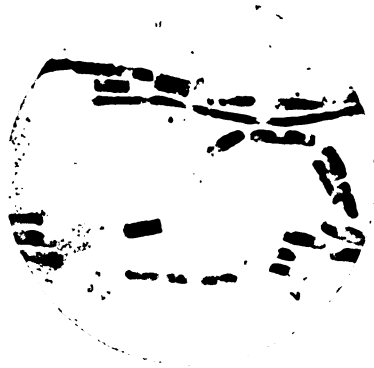


Fig. 16. Rod Form (Bacillus). (From *Kolle & Wassermann.*)

Fig. 17. Ball Form (Coccus). (From *Kolle & Wassermann.*)

classification was much used in the early development of the science as evidenced by the names given to the various forms such as, *bacillus typhosus* and *streptococcus*. Of course, it must not be imagined that a bacteriologist of to-day would make use of this classification alone in identifying any particular bacteria for which he was searching. Many delicate tests are in his possession which include acid reactions, the effect of the bacteria upon different stains and upon different animals, the presence of motor apparatus (flagella), Fig. 15, and a multitude of other tests, the knowledge of which belongs to the technic of bacteriology.

A classification which is an important one in many ways, is based upon the ability of the bacteria to sustain life with or without oxygen,

namely, *aerobic* and *anaërobic*. This classification becomes rather important, in understanding for example, the bacterial action in the intermittent filter, which will be discussed later. The reason for this lies in the fact that, whereas some of the destructive work in sewage is performed by the anaërobic variety, a very important part is performed by the class of bacteria which need air in order to perform their functions, therefore, necessitating an *intermittent* flow of sewage.

Fig. 18. Spiral Form (Spirillum). (From *Kolle & Wassermann.*)

Still another classification of bacteria which will be appreciated by the layman, divides our numerous micro-organisms into *harmless* and *harmful* bacteria—a classification, however, which is not always definite because of the fact that a bacterium often gives markedly different reactions in different animals. For example, the bacillus of typhoid fever, when swallowed by man, will nearly always produce serious and fatal illness, but when fed to cattle will produce no effect. Fortunately for man the number in the first class very much exceeds that in the second; and there is a further comforting thought that notwithstanding the few black sheep in the flock, the great majority are working for our good, in fact, are the principal factors in making this world a habitable one.

Useful Bacteria. Notwithstanding the fact that the ultimate purpose of this paper is to give a general knowledge of the forms which are dangerous to man, and which must be guarded against by proper sanitary methods, a few words in passing regarding *useful* bacteria will not be amiss.

To quote from Elliott's *Household Bacteriology*: "As soon as an organism begins to live it begins to die; that is, certain cells or parts of cells die and are cast off from the rest, in order that the whole body may not be injured. Animals and plants die and become dangerous to animal life, especially to man; in fact, the wastes of life, even of his own, are man's greatest menace. Here comes to his aid

these microscopic scavengers, the bacteria. Through their agency all dead animal and vegetable matter is changed into the chemical compounds or elements of which it was originally constructed and which are themselves either harmless or helpful to the life of the world."

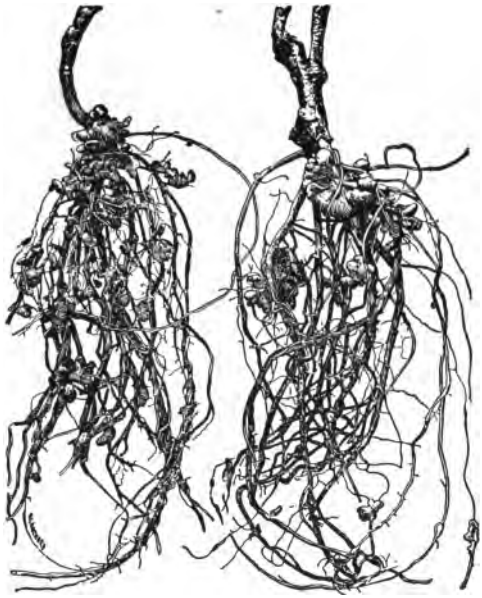


Fig. 19. Roots of Sweet Pea Showing Nodules.

A tree falls in the woods, an animal dies in the jungle; immediately come millions of bacteria from the soil and the air and so modify the dead tissue that it becomes harmless and its useful ingredients are returned to earth.

Nitrifying Bacteria. Again, all animal life is dependent directly or indirectly upon the vegetable kingdom for food, while plants use as their foods, gases, water, and the various salts which are held in solution by the moisture in the earth. One of the most important elements necessary for plant life is *nitrogen*, a substance which the plant is unable to extract directly from the air but must obtain through the soil. This results in the soil becoming impoverished by this continuous demand for nitrogen, until the use of fertilizers is necessary to bring the supply back to normal. It had long been noticed, however, that the soil when allowed to *rest* for a period would of itself, apparently, increase its nitrogen supply. This action is now known to be due entirely to the soil bacteria which have, by their ceaseless action upon the nitrogen of the air, drawn a part of this inexhaustible supply into the ground in such a form that it can be made use of by the plants. This fact has resulted, in recent years, in the practice of inoculating an exhausted soil with artificially grown bacteria, a method, however, which has had only indifferent success,

owing, no doubt, to a failure to understand all the conditions of the problem.

Another fact, long known in agricultural circles, but until recently not understood, has been explained by means of these *nitrifying* bacteria, viz, the fertilizing effect of peas, beans, clover, etc., Figs. 19 and 20. These belong to a class of crops which does not impoverish the soil but rather increases its richness in nitrogen. It has been found

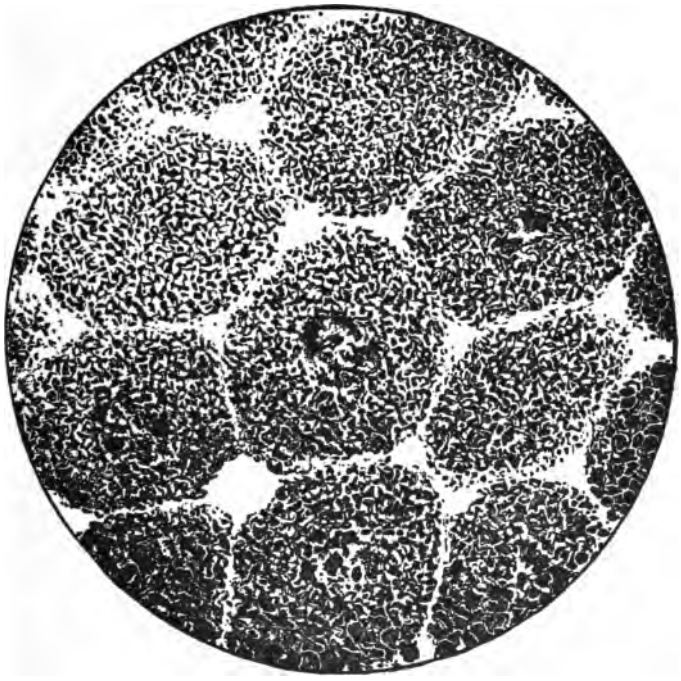


Fig. 20. Cells of Clover Tubercule, Showing Bacilli Highly Magnified.

by experiment that these plants have attached to their roots, nodules or lumps, containing large colonies of these useful bacteria which are storing up nitrogen from the air. The plant, by a process not understood, is able to draw upon these stores to build up its own tissues and so when this *green manure* is plowed under the soil the nitrates which it contains increase the fertility of the earth.

Other Useful Forms. There are many other forms of useful bacteria and only a few can even be mentioned in passing. The tanning of hides involves the treatment of the leather in several fer-

mentation baths, in all of which bacteria are the active agents of fermentation. There are also certain bacterial forms which are active in the formation of indigo, in the ratting of flax, in tobacco curing, butter and cheese making, etc.

"It is seen, therefore, that just as among the hundreds of beautiful flowers in the woods and fields there is the *poison dogwood*; or among the luscious mushrooms there is one deadly variety; or in the large city among the useful law-abiding citizens, there is an occasional thief or murderer; so among the millions of helpful bacteria there are a few which will act harmfully upon the bodies of man and animals." It is undoubtedly true that the study of the helpful forms has done as much to broaden man's understanding and widen the field of his industrial pursuits as the knowledge of the virulent forms has been of service in enabling him to control their operations and prevent great loss of life.

PREVENTION OR CONTROL OF BACTERIA IN THE HUMAN BODY

Toxins. All that has so far been said in regard to bacteria and their action in diseases does not give any idea of the form which this harmful action may take. There are at least three ways in which their influence may be felt; first, by the obstruction produced in the system by the presence of the organisms themselves; second, by the robbery of food which should otherwise have gone to the body itself; and third, by the formation of substances harmful to the body and, therefore, classed as essentially poisonous. For some time the first two of these possibilities only were considered, but soon after, by the active work of Koch and others, the effects of the bacteria in the systems of such susceptible animals as the guinea pig and rabbit, Fig. 21, were carefully studied and the fact was made clear that the third method of influence was the essential one in the operation and growth of disease. It is now universally recognized that the principal method by which the bacteria produce their harmful effects is in the generation of poisonous products called *toxins*, resulting from the operation of living ferments within or upon the organism. In the process of fermentation of apple juice the toxin is alcohol, while in the development of the various contagious diseases, each microbe produces its own toxic substance which must be understood and treated accord-

Fig. 21. Inoculating Guinea Pigs with Germs to Recover Them in the Blood.

ing to its characteristics. In other words, as yeast produces alcohol, so the diphtheria bacillus produces diphtheriatoxin, the typhoid fever bacillus, typhotoxin, and so on.

Vital Resistance and Susceptibility. If the presence of these deadly bacteria in a human organ, for example, is granted, then their activity in new surroundings depends upon whether the soil is to their liking and whether only feeble efforts are put forth to combat them. Nature has provided the body of the average man with a *vital resistance* to disease, that is, a power to withstand the ordinary attacks of these invading hosts. When the resistance is particularly low the body is called *susceptible.* It thus comes to pass that in any contagious disease the energy and virulence of the attacking agents are pitted against the resistance of the patient and a struggle ensues for the mastery. The active control of the sanitary situation, therefore, involves on the one hand, such control of the environment of these active agents of disease that their attacks may be weakened; and on the other hand, such improvement in the general health of the community that the body resistance may be sufficient to withstand attack. The general public is very apt to consider only the violent epidemics which are due to some violation of sanitary laws, and the methods necessary to arrest the progress of the disease, disregarding entirely the slow but ultimately beneficial effects of fresh air, cleanliness, and the many other sanitary precautions which bring about a more healthful condition and a higher body resistance. And yet, when it is remembered that the great epidemics come seldom, affect a small number only, and pass quickly, while filth and bad air act unfavorably on a much larger number and are always present, keeping the people constantly weakened and open to the attack of disease, the latter problem would seem to be at least equally important. It is certainly true that the improvement in general public health renders the occurrence of epidemics less frequent and widespread; hence the chief work of sanitation is in the careful supervision of man's surroundings and the improvement in the habits of those who otherwise would be oblivious to their personal responsibility in the life of the community.

Immunity. When the vital resistance, through either a perfect constitution or exceptional surroundings, becomes abnormally high so that all forms of disease can be thrown off without harmful effect, the organism is said to be *immune.* This subject of *immunity* is

one of great importance but is by no means understood. It is, nevertheless, well known that, in addition to a comparative immunity against infectious diseases which is found in all robust and healthy persons, an astonishing immunity is developed in a body in which a contagious disease has done its work. In the first case several natural agencies might contribute to the routing of the microbes, among which might be mentioned the skin as a mechanical defense, and the gastric and other juices of the body as among the physiological defenses. Of the latter class, might also be mentioned the white blood corpuscles or *phagocytes*, which, according to Metchinkoff, besides acting as degesting cells and as scavengers, are also the chief defenders of the body against the bacteria which have invaded the system. "As soon as the infective agents have penetrated into the body, a whole army of white blood corpuscles proceed toward the menaced spot, Fig. 22, there to enter into a struggle with the micro-organisms."

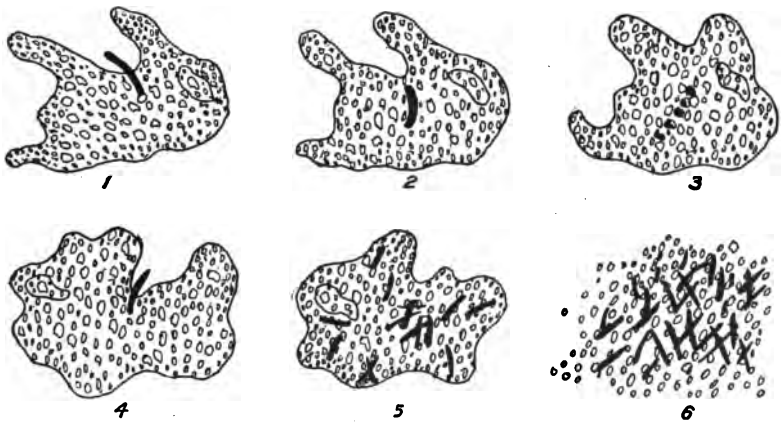


Fig. 22. A Pictorial Combat between Phagocytes and Bacteria. 1, 2, 3, show entry and repulse of the bacterium. 4, 5, 6, represent a triumph for the bacteria.

This natural immunity, or more properly, resistance, is not as perfect as that which is given to the body through the mysterious influence of disease itself. However, bacteriologists, by following the lead which this phenomenon has given them, have discovered methods by which an *artificial immunity* may be developed.

Artificial Immunity. The first systematic step toward this artificial immunity from disease was taken in the case of smallpox. The work took the form of the inoculation of some *matter*, obtained

from eruptions on the body of a smallpox patient, under the skin of a healthy person who chose to suffer a mild form of the disease when well, rather than undergo it in more virulent form and possibly succumb when the body resistance was low. This method had come to Constantinople from the far East, possibly originating with the Chinese, and was first introduced into England in 1717, through the agency of Lady Montagu, the wife of the British Ambassador. Through her correspondence with influential persons in England the method was adopted there, and later in America. To us of this day it is hard to conceive of the terrible ravages of this disease even as late as the middle of the eighteenth century. A writer, Dr. Brooke, in 1766, made the statement that "In the ordinary course and duration of human life *scarce one in a thousand* escapes the smallpox." It would be easy to multiply authoritative statements of the prevalence of the disease, and yet by this simple process of inoculation, and later by the equally efficient but less violent method of vaccination, the disease has become rare in about the same proportion as it was frequent in the days before these preventive methods were inaugurated.

Vaccination. The method of vaccination to prevent smallpox was discovered by Dr. Jenner in 1796. Of course, he knew nothing at that time in regard to the bacterial nature of the disease, and if he could listen to-day to our up-to-date talk about bacteria, microbes, toxins, and antitoxins, he would not understand a word of it; but, nevertheless, he blazed the trail which led, through artificial immunity, to the salvation of man from one of the most dreaded scourges to which he was subject. It was known in Jenner's time that persons who milked cows having sores on their udders due to an infection called *cowpox,* often showed symptoms of the same disease through the appearance of sores upon their hands. These soon healed after a slight illness, and it was later noticed that such persons were nearly, if not wholly, immune to the disease of smallpox. Dr. Jenner studied this carefully and reached the conclusion that if a person were inoculated with a small portion of the material taken from a cow infected with cowpox, this would produce an effect similar to that obtained through the process which had already been practiced, of inoculation with matter from a human smallpox patient. After many experiments, his conclusions were completely verified, and now large and carefully

Fig. 23. Injection of the Diphtheria Culture into the Horse.

Fig. 24. Drawing the Blood from an Immune Horse in Order to Obtain the Antitoxic Serum.

managed establishments are devoted to the preparation of *virus*, as it is called, which can be used in vaccination. By the latter process the susceptibility is reduced to a minimum, but the protection wears off as time passes and re-vaccination is necessary. The present agitation in many localities in regard to anti-vaccination shows how little the general public knows of this disease and the terrible dread which it caused before the preventive methods were discovered. It is curious to see to what extent persons who, of their own free will, or on the advice of their physicians, cheerfully and even eagerly swallow medicines of unknown, possibly deadly, character, will refuse to obey their medical advisors when they recommend vaccination. It is quite true that some of the agitation against vaccination has been caused by impure virus and careless methods of administering it; but even under these conditions, the gain is so tremendous that their criticisms seem idle and irrelvant.

Fig. 25. Sterilized Bottles Full of Blood. The dark portion shows where the red blood corpuscles have settled out, leaving the plasma at the top, from which the serum is obtained.

Antitoxins. Another method of producing artificial immunity was discovered, in 1892, by Behring and Kitasato in their work on diphtheria. It was discovered by them that the serum—the liquid portion of blood after the coagulum has been removed—from an animal which had been made immune to the poison of diphtheria was able, even in a test tube, to neutralize or impair the virulence of this same poison or toxin; and further, that the serum from an animal which was not immune was not able to do this. Clearly then, substances exist in the serum from an immune animal which were not there before the animal was made immune and our present theory of immunity rests upon this fact. The process of making a body immune according to the serum theory may be described according to Dr. William Sedgewick as follows:

"The microbe, or its toxin, irritates the cells of its host. These produce defensive secretions or antitoxins which tend to neutralize the poison or to diminish the activity of the bacillus, or both. If victory is assumed for the cells the condition of temporary immunity or convalescence is found. Victory for the microbe means continued

Fig. 26. Autopsy on Guinea Pig, to Discover Effect of Diphtheria Germs and Recovery Due to Antitoxin.

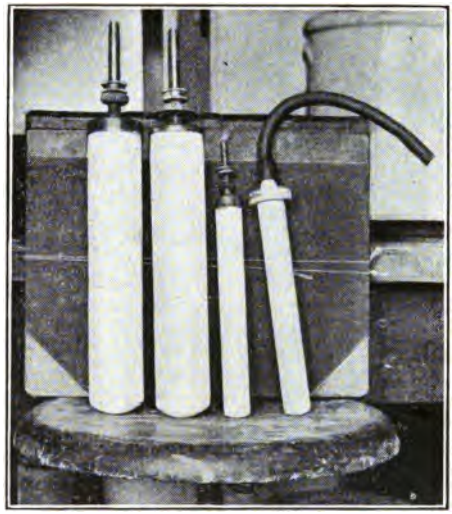


Fig. 27. Filters Used for Filtering the Plasma.

disease or death, as shown in Fig. 22. If it may be assumed that the cells of the body continue to secrete more or less of this preventive substance or that they remain for a long time peculiarly sensitive to even minute doses of the toxin in question, the persistence of more or less immunity can be understood." It is quite possible that the white blood corpuscles are the active agents in producing this defensive secretion.

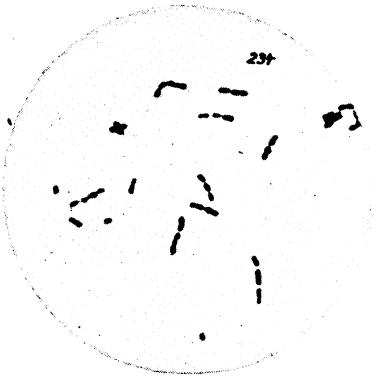


Fig. 28. Pneumonia Streptococcus Culture One Day Old.
(From *Kolle & Wassermann.*)

The methods for the production of the antitoxin serum for diphtheria have been carefully developed. First a pure culture of the

diphtheria bacillus is obtained and a small portion of the infected fluid is injected under the skin of a horse, Fig. 23. The animal contracts the disease in a mild form and soon recovers. These injections are continued at intervals until the horse no longer shows any effects. The animal is now immune and when blood is drawn from it, Fig. 24, and properly treated to allow the red corpuscles to settle out, Fig. 25, the serum from this blood is found to contain the required antitoxin. The effect of this is usually studied by the inoculation of the guinea pig with diphtheria germs, and a further inoculation of the preventing serum. An autopsy, as shown in Fig. 26, reveals the action of the toxins and antitoxins. This serum is carefully filtered through porus cups, as shown in Fig. 27, and then injected into patients actually ill with diphtheria as a reinforcing medicine, or into persons *exposed* to the disease. This method has brought about a reduction of over one-half of the deaths from this disease.

Fig. 29. Tetanus (lock jaw) Bacterial Culture Three Days Old. (From *Kolle & Wassermann.*)

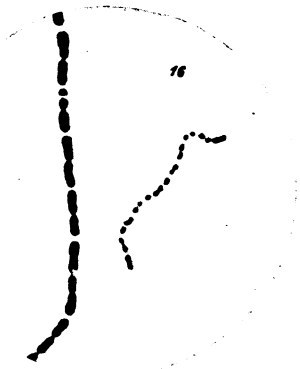


Fig. 30. Streptococci Found in Pus. (From *Kolle & Wassermann.*)

As soon as this antitoxin was discovered for diphtheria, all eager experimenters turned their attention to other diseases with the idea that similar sera could be discovered for pneumonia, Fig. 28, tuberculosis, plague, typhoid fever, cholera, and blood-poisoning. At

the present date, however, few of these infectious bacteria have been brought into captivity. Antitoxic sera for tetanus (lock-jaw), caused by the bacillus shown in Fig. 29, and some forms of blood-poisoning, Fig. 30, have been tried with fair success, but for the most part, efforts have failed. With the knowledge already obtained from bacteriological study, however, sanitary methods have been developed which effectually control typhoid and cholera epidemics, while the *fresh air treatment* and the use of Koch's *tuberculin* in various forms are improving the hold of physicians upon the ravages of tuberculosis.

The facts given in the foregoing summary represent naturally an extremely brief presentation of the essential points in the development of the study of bacteriology but they will suffice to emphasize and make clear the reasons for the preventive methods of sanitation of the present day. It is enough for us to know that *none of the infectious diseases are now believed to rise spontaneously but only more or less directly from previous cases of the same disease.* It is believed that in every instance there must be an actual invasion of, or at least contact with, a susceptible patient by the micro-organism of the disease in question. Once inside or upon the patient the organisms may grow and multiply, producing at the same time their own peculiar poisons precisely as yeast—in wine, beer, or other fruit juices—produces alcohol as one outcome of its peculiar vital activity. The effects produced in the person are believed to be due to the specific poisons of which he may die, or from which he may recover and thereby become immune.

THE PROBLEMS OF SANITATION

*"Twenty-five years ago Mr. Frederic Harrison, writing of the nineteenth century, gave us this picture of London, the largest city of the modern world, and, indeed, of all time.

> To bury Middlesex and Surrey under miles of flimsy houses; to crowd into them millions and millions of over-worked, under-fed, half-taught, and often squalid men and women; to turn the silver Thames into the biggest sewer recorded in history; to leave us all to drink the sewerage water, to breath the carbonized air, to be closed up in a labyrinth of dull, sooty, unwholesome streets; to leave hundreds and thousands confined there, with gin, and bad air,

*Part of a lecture delivered before the Harvey Society, New York, Oct. 26, 1907, by Professor E. O. Jordan, University of Chicago. (Published by the *American Medical Association.*)

and hard work, and low wages, breeding contagious diseases, and sinking into despair of soul and feebler conditions of body; and then to sing pæans and shout, because the ground shakes and the air is shrill with the roar of infinite engines and machines, because the blank streets are lit up with garish gas lamps, and more garish electric lamps, and the postoffice carries billions of letters, and the railways every day carry 100,000 persons in and out of the huge factory we call the greatest metropolis of the civilized world—this is surely not the last word in civilization.

"We need not pause now to inquire whether this characterization of the London of the nineteenth century was correct, or, admitting that it was, whether it is now true of London or any other city; whether the human race at the beginning of the twentieth century is still dazzled and bewildered by its sudden material acquisitions; whether we are even now rushing violently down a steep place into the sea; I would simply ask you to remark the largest part that faults and defects of sanitation play in Mr. Harrison's eloquent indictment. Some of the hardest things said about the nineteenth century by its critics refer to the neglect of public hygiene. Again and again the luxury of a few and the comfort of more are contrasted with the unhygienic conditions under which many others are forced to live and work. Unhygienic conditions in themselves are nothing new. In medieval London, and indeed throughout Europe, the dwelling places and mode of living of the majority of the citizens were far more unwholesome, far more conducive to the spread of infectious disease than in the London of 1882 or 1907. Mr. Harrison himself in another connection thus pictures the life of the Middle Ages:

The old Greek and Roman religion of external cleanliness was turned into a sin. The outward and visible sign of sanctity now was to be unclean. No one was clean, but the devout Christian was unutterably foul. The tone of the Middle Ages in the matter of dirt was a form of mental disease. Cooped up in castles and walled cities, with narrow courts and sunless alleys, they would pass day and night in the same clothes, within the same airless, gloomy, windowless, and pestiferous chambers; they would go to bed without nightclothes and sleep under unclean sheepskins and frieze rugs; they would wear the same leather, fur, and woolen garments for a life time, and even for successive generations; they ate their meals without forks, and covered up the orts with rushes; they flung their refuse out of the windows into the street or piled it up in the backyard; the streets were narrow, unpaved, crooked lanes, through which, under the very palace turrets, men and beasts tramped knee-deep in noisome mire. This was at intervals varied with fetid rivulets and open cesspools; every church was crammed with rotting corpses and surrounded with graveyards, sodden with cadaveric liquids, and strewn with disinterred bones. Round these charnel houses and pestiferous churches were piled old, decaying,

wooden houses, their sole air being these deadly exhalations, and their sole water supply being these polluted streams or wells dug in this reeking soil. Even in the palaces and castles of the rich the same bestial habits prevailed. Prisoners rotted in noisome dungeons under the banqueting hall; corpses were buried under the floor of the private chapel; scores of soldiers and attendants slept in gangs for months together in the same hall or guardroom, where they ate and drank, played and fought.

"At all events the city slum is not a modern institution. The main difference between the medieval and the modern attitude towards unhygienic conditions lies in our having now become awake to the sources of disease and death and to the knowledge that much disease is preventable. The public conscience to-day winces and rebels at the sight of evils once regarded with indifference or helplessness. So long as mankind supposed that, in the language of Cruden's *Concordance*, "disease and death are the consequences and effects of sin," so long did a bewildered resignation accompany the mysterious visitations of Providence. For many this was radically and permanently changed when the germ theory gave to the human race for the first time in its history a rational theory of disease susceptible of experimental verification. When that fact was established that much disease could be prevented, an enduring foundation was laid for works of sanitation.

"The campaign against disease can be carried on in various ways. Individual cases of disease can be nursed with all the care that experience has shown to conduct to recovery, suitable drugs may be administered, surgical interference resorted to, individual peculiarities studied and taken advantage of; in fact, all the resources of modern medicine can be focused on the state of disturbance or abnormality in the individual patient. Such treatment has saved in the past, and will save in the future, many lives dear to friends and family and of incalculable value to country and race.

"As a mass-method of attacking disease, however, it is distinctly palliative and not remedial. There is no man in his right mind who would not rather avoid disease altogether than be healed of a malady even by the most skillful physician. For many and evident reasons prevention must in the long run take precedence over cure.

"Preventive measures fall conveniently into two classes—those dealing with the physical well-being and resistance of the individual, such as diet, muscular exercise, sleep, fatigue, the use of stimulants

and narcotics, and the general efficiency of the bodily functions; and secondly, those having special reference to environmental conditions or affecting many persons or communities. The methods that the individual may adopt to ward off disease and enhance resistance lie within the scope of personal hygiene; those that involve larger or smaller groups of individuals, constitute the province of public hygiene or sanitation.

The Rôle of Personal Hygiene. "The methods for the furtherance of personal hygiene must be largely educative in character, and it must be recognized that the progress possible in this direction is distinctly limited by inherited constitutional factors. The prevention of disease and premature death is in many cases impossible even if the strictest and most efficacious regimen be maintained and if the hostile action of outside agencies be successfully avoided. In other words, some organisms carry within themselves the seeds of decay which germinate early and come to fruition in spite of all individual endeavors. A congenitally feeble or defective mechanism may be strengthened, but cannot be remade. In most instances, however, measures of personal hygiene avail powerfully in promoting normal life and happiness and in some degree in preventing premature death. I need only mention the high resistance to many infectious diseases possessed by the well-nourished, properly exercised, undrugged individual. Improvement in personal hygiene must depend to a great extent on education, must necessarily be slow, and its success in preventing disease be conditioned in large part by the inherited constitution.

Public Hygiene. "Any distinction between personal hygiene and public hygiene cannot in the nature of things be an absolute one. The stream cannot rise higher than its source, the welfare of the group is determined by that of the individuals composing it. More and more, too, the concerns of personal hygiene are tending to become problems of public hygiene. Bodily cleanliness is essentially a personal matter; it would be an absurdity in the present state of public opinion to legislate for compulsory bathing, and yet the establishment of free public baths is everywhere recognized as an important measure of public sanitation. The same thing applies to exercise and the establishment of municipal playgrounds and gymnasia. The principle is perfectly sound. Primarily the function of public

hygiene is both to avert from the community as a whole the consequences of misdoing, neglect or ignorance on the part of any one, or any number, of its members, and to provide for groups of individuals, conditions as favorable for health and happiness as the most intelligent and far-seeing could demand for themselves. Such conditions may not always be those that the least intelligent or most greedy members of the community desire, but from the point of view of public hygiene they are none the less inevitable.

"Up to the present, measures of sanitation have affected chiefly the infectious diseases. This is shown, for example, by the list of the ten leading causes of death in Massachusetts in 1856 and in 1904, Table 1.

TABLE I

The Ten Leading Reported Causes of Death in Massachusetts in Order of Frequency

1856	1904
Consumption	Heart Disease
*Scarlet Fever	Consumption
Brain Disease	Pneumonia
Old Age	Diseases of Brain and Cord
Pneumonia	Diseases of Kidneys
*Typhoid Fever	Cancer
*Dysentery	Cholera Infantum
Heart Disease	Accidents
Cholera Infantum	Bronchitis
Diphtheria and Croup	Diarrhea and Cholera Morbus

"It is here seen that the diseases that have been displaced are largely the infectious diseases. It is not possible in all cases to determine the factors that have been operative in the decline, and in some cases causes beyond our control have perhaps been at work, but undoubtedly measures of quarantine, isolation, school hygiene, and other protective devices adopted by the community have played a part in the shrinking of once prevalent infections. In some instances the effect of methods of sanitation is not to be mistaken. One of the most remarkable, as indeed one of the best understood

*In 1904 typhoid fever had dropped to thirteenth, dysentery to seventeenth, and scarlet fever to twenty-first place.

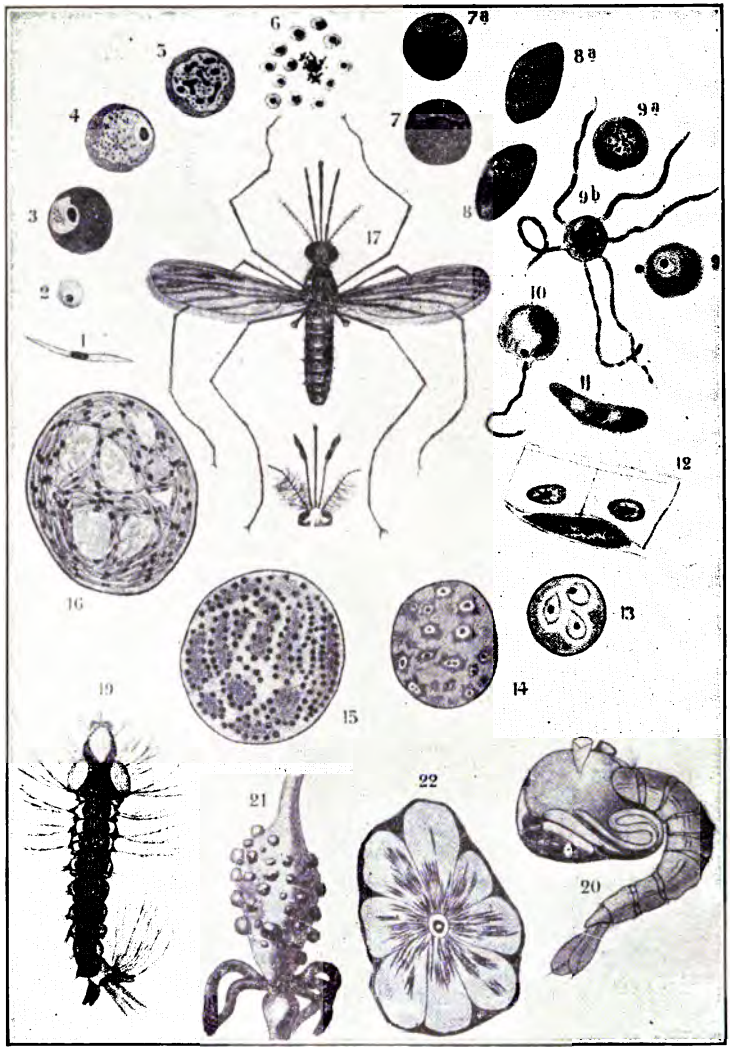


Fig. 31. (After Leuchart-Chun's Wall-Digram.)

ANOPHELES AND THE MALARIA GERM

1, 2. The malaria germ, *Plasmodium*, introduced by a mosquito bite into human blood. 3-5. After penetrating a red-blood cell; its growth at the expense of the latter. 6. Its vegetative multiplication. 7, 8. Crescentic forms (for further development the germs must at this point be transferred from the man to the mosquito). 9. Female germ-cell; 9a, 9b, Male germ-cell. 10. Conjugation of 9 with one of the vibratile arms of 9b. 11. Malaria germ resulting from such conjugation in stomach of mosquito. 12-16. Multiplication (encystment and sporulation) of the malaria germ in the body of the mosquito, with production of many forms like 1 (cycle completed). 17. Female malarial mosquito, *Anopheles claviger;* head of male below. 19, 20. Mosquito larva and pupa. 21. Stomach of mosquito, showing tumors produced by 16. 22. Cross-section salivary gland of mosquito, showing malarial microbes which have wandered into it—from the tumors in 21—and now ready to be transferred with saliva into persons bitten.

examples of the efficacy of sanitary features, is afforded in the influence of improved public water supply on typhoid fever. . . .

"It is surely no small matter that we have come to the point where considerable groups of influential men and women are willing to undertake the task of making plain to the general public the momentous character of these questions. A concerted and persistent campaign of education backed by scientific investigation is likely to have greater weight in moulding public opinion than the isolated appeals of reformers and philanthropists, however timely

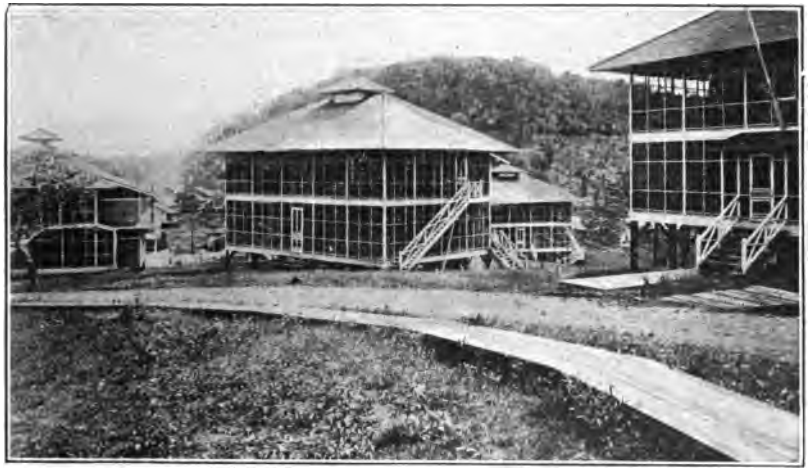


Fig. 32. Houses in the Canal Zone (Panama) Showing Wire Screening Serves to Protect the Inmates from the Mosquito.

and well directed. The great measure of success already achieved by the crusade against tuberculosis at least serves to encourage this belief.

"It is evident, I think, that with the increasing complexity of the social structure, the field of public hygiene will continue for some time to broaden. Many matters affecting the physical well-being of society which are now overlooked, ignored, or regarded as a necessary part of keeping the pace, will come to be seen in their true light."

INFECTION AND CONTAGION

Mediums. As has been already stated, nature has provided a normally high resistance through the mediums of the skin as an external defense against bacteria, and agencies like the gastric juices

Fig. 83. View of Bottle Alley, Colon, September, 1906. These standing pools are the breeding places for the malaria infected mosquito.

Fig. 34. View of Bottle Alley, Colon, June, 1907, Showing Proper Paving and Drainage Methods in the Canal Zone.

and the white blood corpuscles as their enemies within the human system. Infection occurs, under ordinary circumstances, only when these safeguards are broken down in various ways.

The Skin. An apple is provided with its skin and if this is not punctured in any way the apple grows uninterruptedly and develops into the healthy ripened fruit; but if, by a fall or the peck of a bird, this armor is pierced, immediately the organisms in the air enter through this breach, attack the fleshy part of the apple, and begin the work of destruction. It is the same way with the body; a cut may be a very simple matter if caused by an uninfected knife, for example, but if the wound is left open to infection from dust and things which are unclean, or if the instrument which produced the cut happens to be unclean itself and leaves the unhealthy organisms in the wound as it passes through, the effect is the same. The infection soon shows itself in inflammation which may spread locally, fester, and cause great discomfiture if not actual danger when not attended to. If the germs are of an unusually virulent type they may pass into the blood, and if the resistance of the patient is low, may produce extremely rapid changes in the body condition, causing high fever, blood-poison, and possibly death.

Another method of infection through the skin, which has only recently received the attention it deserved, is that of the possibility of infection through the bites of the mosquito and infection by contact with bacteria carried by flies. The former pest has been definitely proved to be responsible for the spread of the characteristic tropical diseases of malaria and yellow fever. In the case of malaria, the fact that the spread of the disease occurred usually near swampy ground, and that the disease was prevalent in country districts rather than in cities, and further that its breaking out was a consequence of extensive soil excavation, all of these idiosyncrasies of malaria fever can now be explained through the creation or maintenance of breeding grounds of the mosquito. Of course, it must not be supposed that the mosquito itself is infected except as it has become so through sucking the blood of a person already subject to an attack of malaria. The contagion, therefore, is due to the fact that the mosquito, so inoculated, passes on the disease germ by biting a person not so afflicted, Fig. 31. It is clear then, that when the available supply of malaria parasites is cut off the bite of the mosquito can no longer convey

infection. The plan therefore which has been followed is in brief, first, to carefully screen all dwelling houses, especially those containing malaria patients, Fig 32, and to kill the malaria bacilli already in the patients by the use of quinine; then by draining off all pools of standing water and properly screening all water reservoirs, rain barrels, and such other feeding grounds, to prevent in a great measure the propogation of mosquitoes in inhabited districts. These methods have been used very successfully in Havana and other cities of Cuba, as well as in Panama, as shown by the improvement of an alley in Colon brought about by the American sanitary engineering corps, Figs. 33 and 34, who have transformed these places from regions where malaria was rampant and the mosquito was a pest from which infection could hardly be avoided, into healthy communities where people can sleep peacefully without any preventive methods against the mosquito. The conclusive evidence obtained by the American Military officers, at great personal risk and with admirable courage—that the yellow fever is transmissible in the same way—has enabled the sanitary expert to practically stamp out this disease, or at least to control it by rigorous quarantine regulations, within certain limited districts. By such methods both of these dread diseases which interfered to such a terrible extent with the active work of the French government on the Panama canal, have been put under almost absolute control, enabling the American government to carry on its work in peace and without any great loss of life.

The Alimentary Canal. The more usual avenues of infection, however, are through actual contact with disease germs which are present in the air or on the clothing of persons who are already diseased. These bacteria find their way through the mouth into the alimentary canal where they are ready to begin their operations if the resistance is not too great. Nature has provided in the digestive track various conditions which are unfavorable to the ordinary bacteria; for example, the acid conditions of the gastric juices is fatal to nearly all of the bacteria present in uncooked food and to very many disease germs. The gastric juice is, however, not often sufficient to cope with these organisms and the alimentary canal may be considered in general a rather favorable breeding ground for the bacteria. Many of these germs are carried on through the digestive system and thrown off without harm to the host. If absorbed by

the blood, the white blood corpuscles or *phagocytes*, Fig. 22, will attempt to devour them, and if their power is sufficient will accomplish their destruction.

Diphtheria germs, for instance, work by finding lodgment upon the tissues of the throat, grow and multiply upon the normal secretions and food materials there present, and in the course of their development produce the poisonous substance already mentioned as the toxin of diphtheria. This first paralyzes or otherwise interferes with the healthy action of the linings of the throat, whereupon, these cells failing to do their duty, an abnormal secretion of lymph produces the well-known *white patches* so common in diphtheritic throats. At the same time the poison is being absorbed into the general circulation, causing the general symptoms characteristic of the disease. The curves in Fig. 35 show how quickly the throats of the school children respond to contagion from the diphtheria germs thrown off from the bodies of those already infected, when they are kept closely confined in ill-ventilated school rooms.

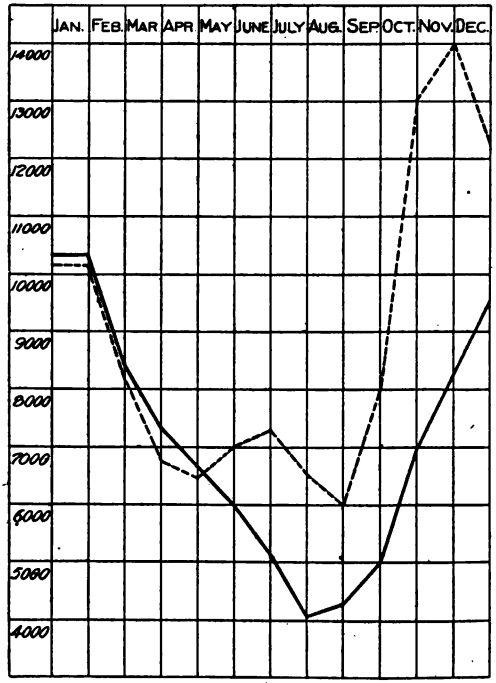


Fig. 35. Diphtheria Chart.
Broken line, school children 5 to 14 years. Solid line, children from birth to 5 years of age.

In Asiatic cholera the infection takes the form of an invasion and an extensive fermentation of the contents of the alimentary canal with tremendous multiplication of the mirco-organisms concerned. At the same time the characteristic poison of cholera is supposedly liberated and absorbed through the walls of the canal, giving rise to the characteristic symptoms such as vomiting, fever, sweating, and delirium.

Sources. If a search is made for the source of these germs which have reached the body from the infected knife or blade splinter, or from the air we breathe, the statement that all the disease germs are spread from cases of the disease itself will seemingly force the responsibility for the creation of these dangerous organisms upon man and other animals. It was formerly supposed that the soil and various other unhealthy materials were extremely fertile sources of infectious diseases; in other words, that the germs not only existed but thrived and multiplied in the earth. It was thought, for example, and is still held by some, that the typhoid fever microorganism passes a portion of its life in the soil, especially in filthy soil. There is no question, however, that to-day the prevailing opinion is that these germs require body contact in order to develop to any great degree. The recent discovery of the rôle played by the mosquito in the conveyance of malaria and yellow fever merely shows that diseases long associated with swamps and stagnant pools have had their sources only in the animal bodies which inhabited such places. If, therefore, it be true that man and other animals are the principal *original sources* of infection, it thus follows as a matter of course that their excreta are its principal original vehicles, Fig. 36. These would include not only discharges from the digestive tract but the nose, lungs, pores of the skin, etc.; involving, in fact, all avenues by which material can be thrown off from the body. It is interesting to note that the expired air from the lungs formerly so much dreaded by those who watched at the bed-side, appears, according to the careful investigations, to be the least dangerous of all excreta, being practically germ free.

Fig. 36. From Excreta of Cholera Patient on the 23rd Day of Sickness. (From *Koile & Wassermann.*)

The *secondary vehicles of infectious diseases* which sanitation must combat are the soil, air, water and animals. From the skin the surrounding air may first become intected and then move on laden

with disease. Likewise the sputum from the mouth or the discharge from the bowels may be slowly mingled with a stream so that the seemingly pure water way contain unseen and unsuspected germs of deadly disease. Or again, the earth impregnated with human excreta may be dried, pulverized, and as dust blown hither and yon by the wind, infect the human throat, and become the means of inflicting diseases such as diphtheria and tuberculosis.

Fig. 37. A Dust Garden. *a*, mould; *b*, bacteria.

THE CARRIERS OF DISEASE

The Soil. As has already been said, the idea that the soil offers a fertile breeding ground for noxious bacteria has been practically abandoned. That it is inhabited, however, by millions of useful living organisms which carry on important organic transformations is freely admitted, and it would not be surprising if among the many, a few of the disease-producing variety, like the microbe which causes tetanus, would be found to grow in some soils. Nevertheless, it may be considered that the body of the earth is quite free from dangerous bacteria except where it forms the medium through which the infected excreta of man and animals can unite with the ground

waters and thus infect the streams and rivers. The surface layers of the soil are not so free from contaminations and, becoming pulverized, rise in clouds of dust to infect the air, irritate the nasal and bronchial passages, and perhaps cause serious afflictions. The presence of the infecting bacteria are easily seen by making a culture as shown in Fig. 37, the spots marked *a* being mould cultures, and those marked *b* are due to dangerous bacteria.

The Atmosphere. *"Few people realize that, with the advent of autumn, the great majority of the swarms of bacteria which have been circulating in the air during the hot summer months take their leave of us and disappear.

"Practically, however, we are all conscious of this fact, for we know what greater difficulties attend the keeping of food sweet and wholesome in the summer than are met with in the winter. . . . Bacterial operations are, however, distinctly favored by the accident of temperature, the warmth of the summer encouraging their vitality and multiplication. We know that as regards mere numbers the bacteria in air may vary from 0 to millions in a couple of gallons, these extremes being dependent upon the surrounding conditions or relative purity of the atmosphere.

"Out at sea, beyond the reach of land breezes, it is no uncommon thing to find none whatever; on mountains and even hills of humble elevation, the lack of bacteria is very marked if there are no abnormal or untoward circumstances contributing to their distribution. In illustration of this, the recent investigations of the air on the summit of Mont Blanc by M. Jean Binot are of especial interest, inasmuch as the altitude at which they were carried out is the highest at which the search after bacteria has so far been pursued. . . . As was to be anticipated, frequently no bacteria at all were found, and it was only when such comparatively large volumes of air as one thousand litres (about 200 gallons) were explored, that microbes in numbers varying from four to eleven were discovered. The air of the country is far freer from microbial life than that of cities; whilst open spaces, such as those afforded by the public parks, are paradises of purity compared with the streets with their attendant bacterial slums.

"That it is no exaggeration to describe streets from the bacterial

*From Frankland's *Bacteria in Daily Life*.

point of view as *slums*, is to be gathered from the fact that much less than a thimbleful of that dust which is associated with the blustering days of March and the scorching pavements of summer, may contain from nine hundred to one hundred and sixty millions of bacteria.

"There can be no doubt, therefore, that dust forms a very important distributing agent for micro-organisms; dust particles, aided by the wind, being to bacteria what the modern motor-car, with its benzine or electric current, is to the ambitious itinerant of the present day. Attached to dust, bacteria get transmitted with the greatest facility from place to place, and hence the significance of their presence in dust. . . . Bacteria, however, survive this desiccation process much better when they are herded together in large numbers than when they have to face such untoward conditions as isolated individuals. This has been well illustrated in the case of diphtheria bacilli, and the difference in their powers of endurance under these respective conditions is very striking. Thus when a few only were exposed to a very dry atmosphere on silken threads, they disappeared after eight days; but when somewhat larger numbers were taken they contrived to exist for eighteen days; whilst when great multitudes of them were herded together, even one hundred and forty days' starvation in these desert like surroundings could not entirely stamp out their vitality.

"This dangerous property possessed by the germs of diphtheria should, if possible, increase the vigilance with which the outbreaks of this disease are watched and dealt with. Abel cites an instance in which a wooden toy in the sick-room of a child suffering from diphtheria was found six months later to have virulent diphtheria bacilli upon it.

"That the bacillus of consumption should have been very frequently found in dust by different investigators is hardly surprising when it is realized that the sputum of consumptive persons may contain the tubercle germ in large numbers, and that only desultory efforts have been made to suppress that highly objectionable and most reprehensible practice of indiscriminate expectoration. Considering that the certified deaths from tuberculosis in 1901, in England and Wales alone, reached the enormous total of 42,408,* and bearing in mind the hardy character of the bacillus tuberculosis when present

*The number in the United States during 1900 was 121,000. (Jordan)

in sputum, it having been found alive in the latter even when kept in a dry condition after ten months, it is not too much to demand that vigorous measures should be taken by the legislature to cope with what is now regarded as one of the most fruitful means of spreading consumption . . . . . .

"Some years ago Messrs. Carnelley, Haldane, and Anderson carried out an elaborate series of investigations on the air of dwelling houses in some of the poorest parts of Dundee. The samples were taken during the night, between 12:30 a. m. and 4:30 a. m., and in their report the authors state that the one-roomed tenements were mostly those of the very poor; 'sometimes as many as six or even eight persons occupied the one bed,' whilst in other cases there was no bed at all. As regards the number of bacteria present in the air in these one-roomed houses, an average of several examinations amounted to sixty per quart; in two-roomed houses it was reduced to forty-six, and in houses of four rooms and upwards only nine micro-organisms in the same volume of air were discovered.

"On comparing the mortality statistics with the composition of the air of dwelling houses of different dimensions, the authors arrive at the following conclusions: 'That, as we pass from four-roomed to three-, two-, and one-roomed houses, not only does the air become more and more impure, as indicated by the increase in the carbonic acid and organic matter, and more especially of the micro-organisms, but there is a corresponding and similar increase in the death-rate, together with a marked lowering of the mean age at death.'

"Mention may also here be made of the investigations made by these gentlemen on the air of *board* schools, which showed that in those buildings where mechanical ventilation was used the carbonic acid gas was three-fifths, the organic matter one-seventh, and the micro-organisms less than one-ninth of what was found in schools ventilated by the ordinary methods. In commenting upon this series of investigations, the authors write: 'When we come to consider that the children who attend the average school for six hours a day are during that time subjected to an atmosphere containing on an average nearly nineteen volumes of carbonic acid per 10,000, and a very large proportion of organic matter, and no less than 155 micro-organisms at least per quart, we need not be surprised at the unhealthy appearance of very many of the children. It must also be borne

in mind that many of them are exposed for nine hours more to an atmosphere which is about five times as impure as that of an ordinary bedroom in a middle-class house. They are thus breathing, for at least fifteen hours out of the twenty-four, a highly impure atmosphere. The effects of this are often intensified, as is well known, by insufficient food and clothing, both of which must render them less capable of resisting the impure air. The fact that these schools become, after a time, habitually infected by bacteria renders it probable that they also become "permanent foci of infection for various diseases and particularly, perhaps, for tubercular disease in its various forms." ' "

Illustrations could be multiplied without number to show the harmful effects of impure and insufficient air as found among the dwellings of the poor; and the many efforts of municipalities and private philanthropic individuals to improve these conditions, testify to the active state of the public conscience, and to an appreciation of the value of sanitary methods in bringing about a better condition of the public health.

Filth and Filth Diseases. A rather important change of ideas due to modern bacteriology is the present view of filth and filth diseases. In the earlier days before the bacteria and their ways were understood there were many *filth diseases* which were so named because of the idea that filth was not only the vehicle but the actual breeder of the infectious disease. This was applied, for example, to typhoid fever, a view which has since been entirely abandoned. The modern theories of filth and its dangers are very different from these. It is first and always a convenient vehicle of disease but, in modern sanitation at any rate, it is seldom more than this unless it serves to produce a depressing effect, thereby lowering the body resistance. In other words, filth is looked upon as dangerous by the sanitarian of to-day chiefly because it may hold in its composition the germs of disease in more or less virulent form but not because it may be a *breeding place.* Therefore, there are no *filth diseases* as such, and sanitary boards have no design, in the care of the dirt of the streets or the disposal of putrifying garbage and refuse, other than the removal, by cremation, by dumping in the sea, or plowing under the soil, of some of the *carriers* of diseases and the reduction thereby, of the chances of contamination of its public supplies of water, milk, etc,

Personal Cleanliness. A love of cleanliness is perhaps not inborn but is the result of civilization, of education, of a development of a bodily righteousness which shows itself in an abhorence of dirt either on one's person or his surroundings. In this day of understanding there is an added incentive in the fact that to be clean is, at least in a measure, to be free from infectious diseases, and this, coupled with an intelligent care of one's surroundings, of the supply of food, of milk, and of water, brings about the best possible condition of public health. The use of cooking methods, *i. e.*, high temperatures in the preparation of our foods, has been one of the most valuable aids in the destruction of our invisible enemies, aside from its value in making eating worth living for. Again, some of the channels through which personal uncleanliness or the more virulent personal infections have been wont to act, have received especial attention during the past few years. The public drinking cups, communion cups, roller towels, barbers' shaving mugs and razors, and the many other articles which, if used in common, tend to bring about the transfer of the disease germs from one body to another, have been, where possible, abolished and a sufficiently widespread knowledge of and sentiment against such things have been instilled into the public mind to bring about the proper sanitary regulation. Public drinking fountains of an approved type are being installed everywhere, while the old *town pump* is rapidly becoming classed as an *undesirable citizen.*

Sewage a Carrier of Disease. The disposal of the waste products of life by means of a well-ordered sewerage system has become well-nigh universal and, as sewage is at all times more or less highly infected with disease germs, its final disposition becomes an important factor to the sanitary expert. The old adage—"Eternal vigilance is the price of peace"—applies not only to war against municipalities and powers but to the bacterial campaigns as well. As Dr. Sedgewick puts it "the chain of public health is no stronger than its weakest link, and therefore, no matter how clean and wholesome all other conditions may be, if there is one point at which the germs of infectious disease may find admission into the body, danger may be imminent."

Disposal by Running Streams. Up to within a few years ago there was a well-defined theory that "running water purifies itself."

This fact was used to justify the practice by many towns and cities which were located on the banks of rivers and lakes, of drawing their water supply from above the town and emptying the sewage below, without a thought as to possible conditions which would result in a contamination of the water supply by the sewage of the town above or the influence of the town's own sewage upon the water supply of the people below them. There were, therefore, a number of cases of dangerous polution of river waters, which resulted in epidemics of greater or less severity. The theory itself is based upon the obvious fact that although a very large amount of sewage might be suddenly poured into the stream at a given point, it is only necessary to follow the stream for a comparatively short distance to find the results of such pollution, if not entirely wanting, reduced to a small amount. Naturally only one conclusion could be drawn, viz, that the water had purified itself. A point which was not taken fully into account in the early history of this method—the amount of purification due to dilution—has been more carefully worked out, with the result that extreme care is now exercised in furnishing a proper proportion of water for a given amount of sewage and in the use, where necessary, of filters either for the sewage or for the water supply. Several other elements, as for example, swiftness of the current, nature of the sub-soil, and time element have been taken into consideration with the result that the method of sewage disposal by flowing streams when accompanied by the proper amount of regulations has been found a very useful, inexpensive, and not at all dangerous practice.

The use of lakes as sewage depositories has also been made with considerable success and unless the volume of sewage proved too great, as in the case of Chicago, the practice of drawing the water supply from this same lake at a properly distant point, has not been found dangerous. In all of these cases the factors, in addition to that of dilution, which contribute to the extermination of the bacteria, are the coolness of the water, which produces either death or inaction; scarcity of food due to the excessive dilution; and the slow settling to the bottom of the sediment, in which the bacteria are growing.

Intermittent Filtration. In a previous discussion of the various types of useful bacteria, the fact was mentioned that there were in the earth many forms of microbes of the *nitrifying variety*, whose office it was to transform organic material into inorganic substances

which the plants could use as food. These useful micro-organisms can account for the disappearance of the fertilizer which the farmer spreads so generously over his fields and plows into the soil each year, and the products of its decomposition are the things which make the difference between fertile and barren soil. If, then, the sewage is allowed to flow out upon an area, there to soak into the earth and give to these bacteria the opportunity of transforming the dangerous material into harmless and, in fact, needful nitrates, this constitutes a very useful and exceedingly effective method of sewage disposal. It is one of the most primitive methods and has been used to very good advantage by cities as large as Berlin.

The early exponents of this method considered that the purification was due in a large measure to an oxidation through exposure to the air, and it was with this idea of the process that the Rivers Pollution Commission of Great Britain, appointed in 1868, carried on many valuable experiments, resulting in the adoption of the method in England and Germany. However, no further data of particular importance were obtained until some most interesting experiments were taken up along modern bacteriological lines by the state of Massachusetts. In 1886, a commission was appointed to go into the subject with great thoroughness and establish an experimental station, which, by the way, was probably the first one of its kind. These experiments were extremely exhaustive in character and covered the range of purification of sewage upon land by intermittent filtration, and by electrical and chemical separation. The method of intermittent filters is one of the most useful and will be the only one discussed.

This method had been used with considerable success in England and Germany, but the knowledge available was very limited, and there was no assurance that conditions of climate, soils, sewage, etc., would not make impossible the adoption of the same methods in Massachusetts. Accordingly, a series of careful experiments were begun to test the purifying capacity of various soils common in Massachusetts. For this purpose a number of large wooden tubs of sixteen feet in diameter were used which were carefully filled with different materials ranging from muck and garden loam on the one hand, to different grades of sand on the other, the latter ranging from fine sand even to large pebbles. The soil or sand to be tested was

in each case supported by a layer of stone and gravel and drained underneath through a pipe which emptied into a large measuring basin. The sewage to be experimented upon was drawn from one of the main sewers of the city of Lawrence, and was the ordinary domestic city sewage free from manufacturing wastes. The result was astonishing to say the least. Many people who witnessed the experiments felt certain that the filters would become clogged and foul. They did not know that Berlin disposes of all its sewage upon land. They forgot that the farmer lays on yearly a layer of filth and plows it into the ground. As soon as a few days had passed and the filters had become thoroughly established, the filtrate showed a decided improvement and soon was bright and clear. Analyses showed that the output was *purified sewage*, comparatively free from odor, and with only a few scattered bacteria. The surprising part of the whole matter was that the filters showed no signs of clogging and no disagreeable odors developed. It was a strange fact that the fine loam which many supposed would be the most efficient in producing purification, was really the least effective, the texture being too fine to allow sewage to percolate freely. On the other hand, the sands all worked to good advantage, the fine grains working best; but strange to say the only office of the grains of sand or the pebbles was that of providing the little pits on their surface as places in which the *bacteria* could lodge and thereby detain and work over the organic matters in the sewage. In other words, the little channels through which the sewage passed became populated with swarms of bacteria which were able to modify the material held in solution so that it passed out of the filter in harmless forms, that is, the action of the intermittent filter was almost entirely chemical and bacterial. It is clear, therefore, that this process is not *filtration* in the strict sense of the word but merely a method of splitting up the sewage by means of the millions of canals between the sand grains so that the bacteria, which lodge along the walls of these canals, can effectually dispose of the harmful products. In this process both the aërobic and anaërobic varieties of bacteria are active, a fact which was brought out by the necessity of the flow of sewage being *intermittent* in order to obtain the best results; a continuous flow prevented the aërobic bacteria from obtaining the air necessary for their active existence.

The results of these experiments were quickly applied in Massa-

chusetts and elsewhere. All that needed to be determined was whether the soil of that particular section was of a quality to produce the proper purification, after which the method of land-disposal of sewage could be installed with perfect confidence. As to where the numerous living bacteria always present in crude sewage have disappeared, it might be said that some are mechanically detained in the upper layers of the earth, others perish from lack of food either near the surface or probably in the lower layers of the filter, while those that pass through the filter undoubtedly are so weakened by the lack of food in the filtered sewage that they soon die. At any rate, it has been found in most cases that the water after passing through well-built intermittent filters is sufficiently pure to be drunk with impunity. There are many other methods which have been advocated and brought into more or less general use, but the scope of this article will allow only the mention of such devices as irrigation and sewage farming, chemical precipitation, electrolytic action, and the fermentation or septic process. Each may have a particular value under certain local conditions, none ever becoming universal, but all contributing to the destruction of dangerous material and the improvement of sanitary conditions in general. For further information concerning sewage disposal and purification, the student is referred to pages 134 to 149 in Marston's *Sewers and Drains.*

Water an Active Agent in the Spread of Disease. *"It may be safely assumed that there are few natural waters on the surface of the earth that do not receive a perceptible amount of the sewage, drainage, or waste resulting from human activity and habitation. Now the experience of the human race has shown that many of these natural bodies of water are used as a source of water supply by considerable populations without any strikingly noticeable injurious effects. If all the dangerous elements, or, to put it more specifically, all the pathogenic (disease causing) bacteria, entering bodies of water remained there in their original numbers without change, it needs little imagination to picture the difficulty there would be in obtaining a supply of even moderately wholesome drinking water. We know that this is not the case, and it is apparent that in nature some sort of change occurs which results in the destruction or dis-

*From *Natural Purification of Streams*, by Professor E. O. Jordan, University of Chicago.

appearance of the offensive and disease-producing elements that are introduced from time to time into most bodies of water.

"It has been wittily said that what is wanted in a drinking water is innocence rather than repentance, but it must be remembered also that very few large communities are in a position to obtain a virginally pure supply. In practically every civilized country the rivers, large and small, receive the sewage or drainage of a more or less extensive population; and the same is true of the large ponds and

Fig. 38. Water Supply System in a Large Cuban Town.

lakes. It has been estimated by Hazen that the water supplied to approximately 52 per cent. of the urban population—in cities of over 25,000—of the United States is unsatisfactory. The large and increasing consumption of water by the inhabitants of modern cities and towns renders the obtaining of a sufficient quantity of uncontaminated water always difficult and in most cases impossible. For the majority of public water supplies, recourse is had to sources known to be more or less polluted at some stage in their history. The reckless practice of some cities in using such water without

artificial purification shows that a considerable degree of natural purification must occur, otherwise the consequences of the neglect of elementary precautions would be far more disastrous than they are." For example, the water system for a large town in Cuba, Fig. 38, would hardly be considered ideal from a sanitary standpoint. Yet even with these primitive methods, cases of infections are no doubt comparatively rare.

Cholera. The most common of the dangerous infections to which are attributable the pollution of the water supply are cholera and typhoid fever, and a study of the occurrence and behavior of these maladies should be of great interest to the sanitarian. Both attack the digestive tract, Fig. 39, but the former is much more rapid in its development and more deadly in its effects. It has been the cause of many serious epidemics of which the one in London, in 1854, and the one in Hamburg, in 1892, will be taken as typical. The epidemic of 1854 occurred in St. James' Parish, a district inhabited by about 36,000 persons, and the deaths from cholera amounted, for a period of seventeen weeks, to 700, or about 220 per 10,000. During this same epidemic a neighboring parish had only nine deaths in 10,000. The origin of the infection was for some time in doubt but finally, by the very careful and skillful deductions of Dr John Snow and others, the finger of suspicion pointed to a public drinking pump in Broad street, Fig. 40. The handle of the pump was at once removed, and a subsequent investigation of the surroundings, made by Mr. York, showed a startling source of contamination. Of course, at that time, bacteriology was in its infancy, and the cholera bacillus had not been identified; consequently, the information regarding the occurrence of cases within the district, the deaths among those who used the Broad street pump, the influence of this same well upon cases in other districts, the exemption of certain factories which had their own

Fig. 39. Typhoid Bacillus Colony. (From *Kolle & Wassermann.*)

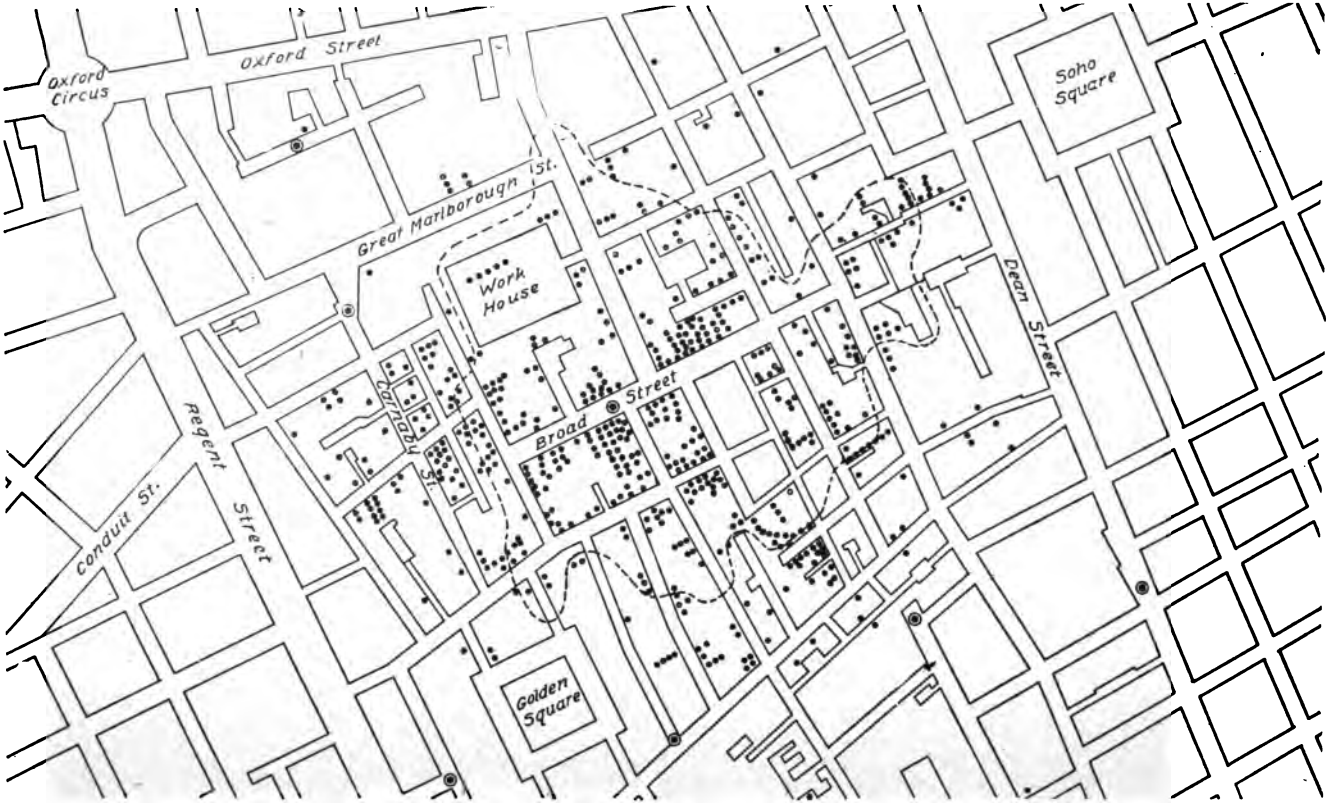


Fig. 40. Asiatic Cholera and the Broad Street Pump, London, 1854.
Large dots show location of pumps; small dots, location of fatal cholera cases; broken line, boundary of equal distances between Broad street pump and other pumps. (From *original map* by Dr. John Snow.)

drinking water supply, all of this material had to be collected with painstaking care. If the authorities had known what we know now, an analysis of the water would have shown at once its infected condition. As it was, the investigation of the surrounding soil showed that a defective drain, foul with the excreta from the inmates of a near-by house, one of which had an attack of cholera, had caused the contamination.

The cholera epidemic at Hamburg, occurring as it did in 1892, after the methods of bacterial detection had been fairly well developed, proved a most instructive though costly lesson in sanitation, and its occurrence brought to the notice of the scientific men the danger of accepting the theory of purification of streams, without due regard to conditions. To quote again from Frankland's *Bacteria in Daily Life*—"In the year 1885, Dr. Koch's new bacteriological water tests had been introduced in the examination of the London water supply and yet their acceptance at that early date had not been sufficiently general to make their influence felt in many cities on the Continent. The general public was waiting for a startling demonstration which came to hand in this cholera epidemic in Hamburg and Altona. These two cities were both dependent upon the river Elbe for their water supply but, whereas in the case of Hamburg the intake was situated above the city, the supply for Altona was abstracted below Hamburg, after it had received the sewage of a population of nearly 800,000 persons. The Hamburg water was, therefore, to start with, relatively pure when compared with that destined for the use of Altona, but let us see what was the fate of these cities as regards cholera. Situated side by side, in fact with nothing in their surroundings or the nature of their development to especially distinguish them, in the one, cholera swept away thousands, while in the other, the scourge was scarcely felt. In Hamburg the deaths amounted to 1,250 per 100,000, while in Altona, to but 221. So clearly defined moreover, was the path pursued by the cholera that the street marking the division between the two cities showed numerous cases of cholera on the Hamburg side and none on that of Altona."

In seeking an explanation of this anomalous situation it must be remembered that the Hamburg water to start with was supposedly in a comparatively pure condition, and had been delivered in Hamburg just as it was drawn from the river; whereas the Altona water,

though much more foul when taken from the river, had been carefully filtered through sand before delivery. Evidently the waters of the Elbe had become infected by cholera germs above Hamburg, probably from a case on ship-board, and as no provisions for removing the germs were made, they were able to enter the bodies of the inhabitants and accomplish their deadly work. Altona's experience gave abundant testimony to the efficacy of the sand filters, as these were able to kill the large proportion of cholera germs which reached the water supply through the infected sewage of Hamburg.

It is a curious fact, however, that after the ravages of the cholera had almost died out in Hamburg, suddenly an unexpected epidemic occurred in Altona, which, after a searching inquiry by Dr. Koch, was traced to the fact that during the winter one of the sand filters had become frozen, and this rendered it incapable of retaining the bacteria which passed through it. As the water supplied to the system came from all the filters, only one of which was defective, the bacteria were so diluted that this epidemic did not prove very severe. It is needless to add that, with this severe experience as a lesson, the city of Hamburg and, in fact, many other cities of the Continent, were not slow in introducing filters in connection with their water systems.

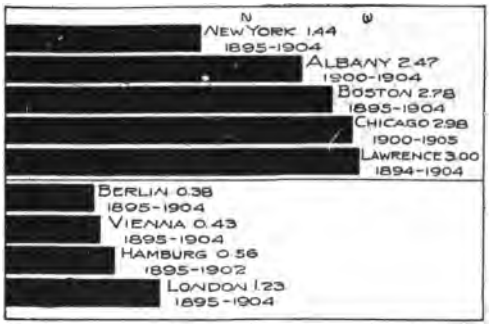


Fig. 41. Typhoid death rates in American and European cities, Albany, Lawrence, and Hamburg, after installation of filters; Chicago, after opening of the sanitary drainage canal. The remarkable case of the City of Washington, D. C., is purposely left out. There the installation of a modern sand filtration plant (November, 1905), was followed in the next year (1906) by a higher typhoid death rate (4.93) than had been recorded for either of the three preceding years (1903, 4.50; 1904, 4.38; 1905, 4.39). (From Jordan's *Problems of Sanitation*.)

Typhoid Fever. Notwithstanding the swift ravages of cholera, its deadly attacks are comparatively infrequent, and, in addition to this, our bacteriological friends have been able to bring the disease under nearly perfect control. Not so, however, with typhoid fever, which is much more prevalent and is moreover, difficult to regulate owing to the slow development of the bacillus. This micro-organism does not make its presence known for about two weeks after infec-

tion has occurred, and consequently if this infection has come through the water supply, all signs of the bacteria have disappeared from the water in that length of time. Yet, in spite of these uncertainties, the evidence has long pointed to the drinking water as being the chief agent of infection in typhoid, and, therefore, the efforts of the sanitarian have been to improve the condition of public water supplies either by changing the sources or by the establishment of filters. The improvements in Europe have been of a more substantial character than those in the United States as evidenced by statistics shown in Fig. 41, these differences being largely accounted for by the fact that the greater density of population in the old country necessitates more care and inspection of the water and milk supplies.

To show the apparent round-about methods of the infections, the case of Plymouth, Pa., in 1885 is cited, the facts coming indirectly from Dr. S. H. Taylor's report contained in the *First Annual Report of the Pennsylvania State Board of Health*, 1886. Plymouth, at this time, was a town of 8,000 inhabitants and had an apparently excellent but limited supply of water from a mountain stream. On this stream, the Plymouth Water Company had from time to time established reservoirs to conserve the supply until, at the time of the epidemic, it had a series of four such receptacles with a total capacity of ten million gallons. The situation from the standpoint of the sanitary expert was further complicated by the fact that the month previous to the outbreak, pumpings from the Susquehanna river were used to help out the reservoir supply which had been found inadequate. In April, the typhoid storm broke and as a result, out of 8,000 inhabitants 1,104 were taken ill with typhoid fever and 114 died. The investigations of this fearful outbreak proved, after careful search and painstaking labor, that the company's reservoirs had been at fault and that the whole supply had been contaminated through carelessness in handling a virulent case of typhoid which had occurred in a house situated on the bank of the mountain stream, just below the highest reservoir.

A man in this house had a long illness of typhoid lasting from January 2nd until April, and during the whole time, the night nurse had made a practice of throwing out the excreta on the snow and frozen ground near the bank of the stream. The spring rains of March had undoubtedly washed this into the stream, thereby in-

fecting the third reservoir. On the evening of March 26th, the superintendent of the water company visited the reservoirs and found practically no water in the first and second but a good deal in the third, due to the fact that the pipe leading from No. 3 to No. 2 had been frozen up. The superintendent promptly had this thawed out, which allowed the infected water in the third reservoir to enter into the water system and produce the epidemic. Dr. Taylor in his conclusions, says:

"It is safe to say that this was one of the most remarkable epidemics in the history of typhoid fever, and it teaches us some important lessons, at fearful cost. One is, that in any case of typhoid fever, no matter how mild, nor how far removed from the haunts of men,

TABLE II

Deaths per 100,000 Inhabitants

	From Apr., 1888, to Mar., 1889	From Apr., 1889, to Mar., 1890	From Apr., 1890, to Mar., 1891	From Apr., 1891, to Mar., 1892	From Apr., 1892, to Mar., 1893	Average Apr., 1888, to Mar., 1893
Concord, N. H.	70.5	29.5	53.0	29.4	11.8	38.8
Manchester, N. H. .	29.9	41.8	43.6	11.15	20.7	29.5
Nashua, N. H.	68.9	42.5	5.3	89.8	31.8	47.7
Lowell, Mass.	86.3	83.9	195.4	81.7	85.6	106.61
Lawrence, Mass. . . .	125.2	118.1	187.0	91.6	114.1	127.2
Haverhill, Mass	22.8	30.3	33.9	30.2	64.0	46.3
Newburyport, Mass.	14.4	28.8	57.6	28.8	50.4	36.0

the greatest possible care should be exercised in thoroughly disinfecting the poisonous stools. The origin of all this sorrow and desolation occurred miles away, on the mountain side, far removed from the populous town, and in a solitary house situated upon the bank of a swift-running stream. The attending physician did not know that this stream supplied the reservoirs with drinking water. Here, if any place, it might seem excusable to take less than ordinary precautions; but the sequal shows that in every case the most rigid attention to detail in destroying these poisonous germs should be enjoined upon nurses and others in charge of typhoid fever patients, while the history of this epidemic will but add another to the list of such histories which should serve to impress medical men, at least, with the great necessity for perfect cleanliness—a lesson which mankind at large is slow to learn."

Dr. Sedgewick, during the progress of his monumental work as biologist to the State Board of Health of Massachusetts, investigated an epidemic of typhoid fever in the towns of Lowell and Lawrence, which are both situated on the Merrimac river and obtain their water from it in the raw condition. Several other towns of New Hampshire and Massachusetts situated on this same river were like Lowell and Lawrence as to climate and pursuits, but, unlike them, obtained their water supply from pure mountain streams and the typhoid fever mortality was correspondingly low as shown in Table II.*

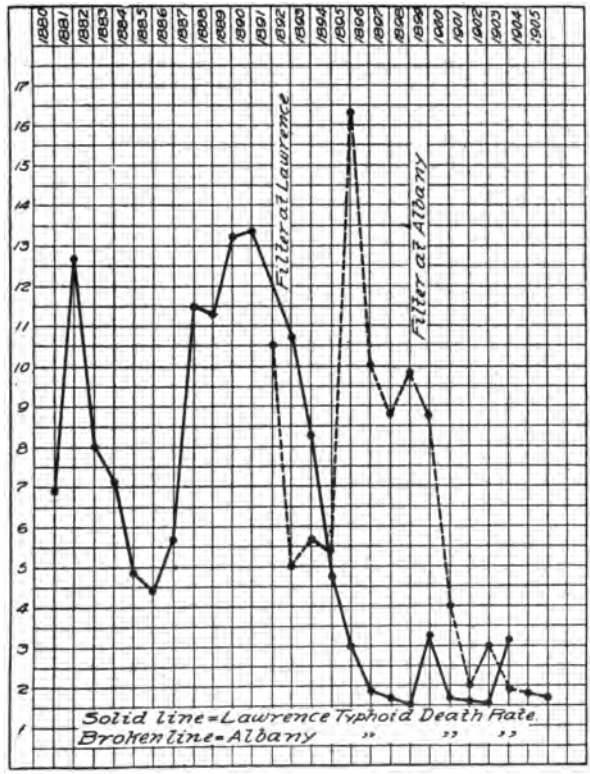


Fig. 42. Curves Showing the effect of the Introduction of Filters on the Typhoid Death Rate in Lawrence and Albany.

During the year of the epidemic, 1890-91, as will be noticed by consulting the table, the typhoid cases in Lowell and Lawrence jumped to nearly double the normal, which was in itself high enough. About 1,500 cases were identified in these two cities during the period of greatest infection and as Lawrence was only nine miles below Lowell, it was evident that in this case the theory of *purification of streams* had broken down. It was very clear that a change of method was imperative and the city of Lowell obtained a ground water supply while the city

*From Sedgewick's *Principles of Sanitation and the Public Health.*

of Lawrence installed filters. The result of this change in Lowell, was the reduction of the deaths in 100,000 population from 97 to 21, and in Lawrence, from 121 to 26, Fig. 42. Similarly the installation of approved filters in Zurich reduced the death rate from 76 to 10; in Hamburg, from 47 to 7; in Albany, from 104 to 38. Vienna, by abandoning the Danube as a water source, lowered its typhoid fever death rate from over 100 to about 6; and Chicago, by the use of the 4-mile intake in Lake Michigan, diminished her rate from 115 to 35. Some of these facts are shown graphically in Fig. 43, taken from Fuertes' *Water and Public Health.*

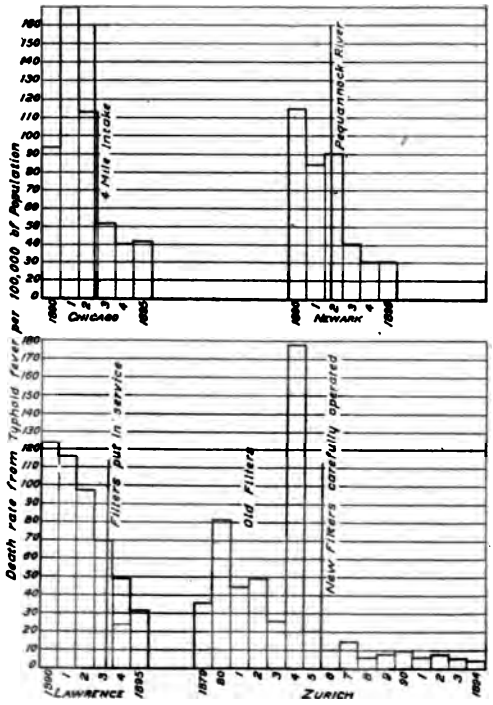


Fig. 43. Graphical Illustration of the Coincidence of the Drop in Typhoid Death Rate with Improvement of Water Supply.

A recent and very instructive example in support of the theory of *purification of streams* is given by the use of the Chicago drainage canal as the carrier of the sewage of Chicago into the Illinois river. Following the more recent opinions regarding the fallacy of this principle, an injunction was gotten out by the State of Missouri against the State of Illinois and the Sanitary District of Chicago, to restrain them from emptying the Chicago sewage from the drainage canal into the Illinois river and thence into the Mississippi, a method which, according to the claims of the plaintiff, prejudiced the St. Louis water supply, which was obtained from the Mississippi. The testimony in this case was most voluminous and expert opinions from the acknowledged authorities of the country were heard during the

session. It would be impossible to even review the mass of data which was collected, but some of the most salient facts are taken from Professor Jordan's monograph on *Natural Purification of Streams.*

"Stripped of all technicalities, the question at issue in the suit on the Chicago drainage canal really is, how far can typhoid bacilli travel in the water of a particular flowing stream and arrive in such a condition as, in the legal phrase, 'to constitute a menace and a danger' to the inhabitants of a distant city or state. It is obvious that the problem is not one of space so much as of time; that it is not so much the distance over which a bacillus has to pass as it is

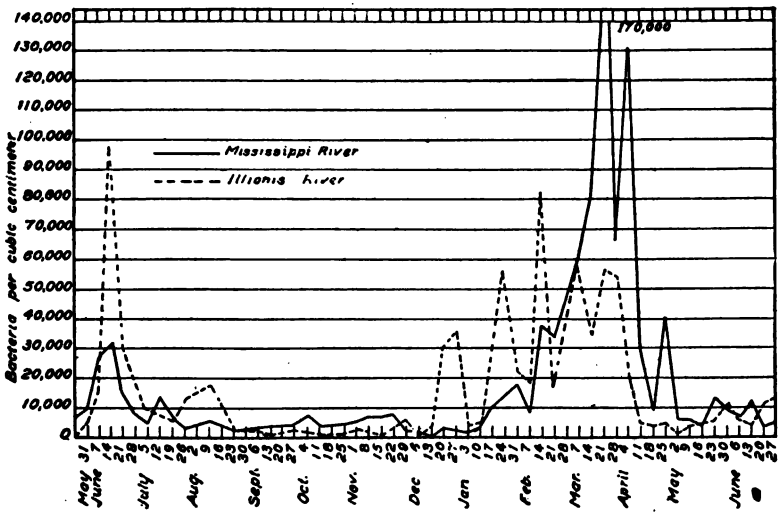


Fig. 44. Curve Showing Bacterial Content in Mississippi and Illinois Rivers for One Year. (From Government Report on River Pollution.)

the time consumed in traversing the stretch of river between the two points. The problem at bottom is essentially that of the longevity of the typhoid bacillus in a given water, whether of a river or a lake. As is well known, the conditions affecting this longevity are many and varied, and the experimental evidence shows that the length of life of this micro-organism is greater in some waters than in others and is influenced by a variety of concomitant conditions. Practically, then, *every inquiry into the alleged self-purification of streams must partake of the nature of an independent and separate investigation,* and must, for the present, be carried on without too much reference to the results obtained under other conditions. It has rarely been found

possible to experiment directly with the typhoid bacillus under conditions identical with those obtained in a given river. It is therefore necessary to rely provisionally upon data of an indirect and inferential character, and it is these latter only that are ordinarily considered in a study of any particular case. The indirect evidence is of several kinds and of different degrees of value."

Many cases are on record of the coincidence of water pollution at a certain point with the appearance of typhoid fever at various other points along a water course—with the allowance of a proper

TABLE III

Desp'aines and Illinois Rivers, Chicago to Grafton

Stations Collecting	Distance from Bridgeport in Miles	No. of Colonies per c.c.	No. of Determinations
Bridgeport	0	1,245,000	19
Lockport	29	650,000	30
Joliet	33	486,000	28
Morris	57	439,000	26
Ottawa	81	27,400	26
LaSalle	95	16,300	31
Henry	123	11,200	29
Averyville	159	3,660	30
Wesley City	165	758,000	22
Pekin	175	492,600	29
Havana	199	16,800	26
Beardstown	231	14,000	26
Kampsville	288	4,800	19
Grafton	318	10,200	28

time interval—such as the one already mentioned of the Merrimac river; but, Professor Jordan continues, "No such relation could be traced between the prevalence of typhoid fever in Chicago and St. Louis. If such a connection obtained it would be supposed that the curves of the disease would be much alike and that the St. Louis curve would be slightly retarded in time. As a matter of fact a comparison made by the writer of the published deaths from typhoid fever in these two cities by months and by years showed no relation whatever as evidenced by the curves, Fig. 44. Sometimes the Chicago minimum and maximum rates precede those for St. Louis by a period of from two to eleven months; sometimes they follow the latter, and

sometimes they coincide with them. A similar outcome attended the attempt to connect high water or low water stages in the Illinois river with typhoid fever in St. Louis.

"The analytical data may next be considered. It is my opinion that the ordinary chemical sanitary water analysis, at its best of doubtful value, is not well adapted for throwing much light upon the problem of the self-purification of streams. The chlorine determination can have practically no significance, and even the determination of the nitrogen compounds is of little real importance. It cannot be said that the process of decomposition and the processes that lead to

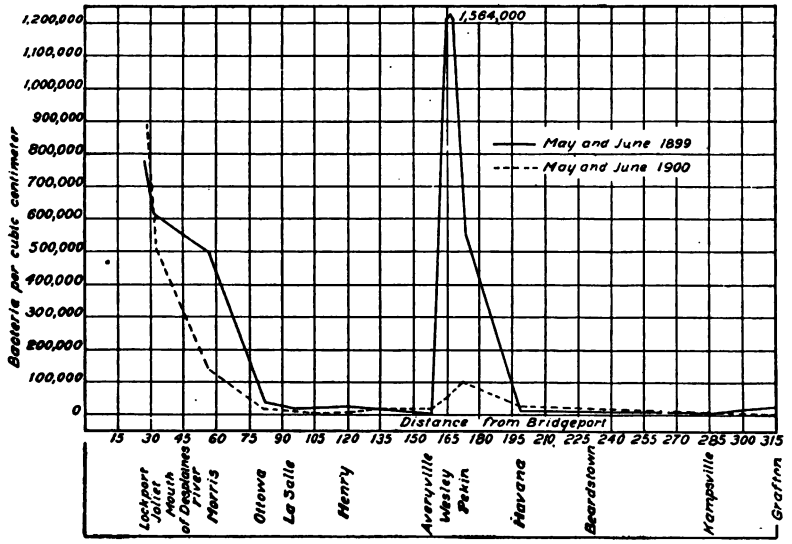


Fig. 45. Bacterial Content of Illinois River from Bridgeport to Grafton.

the destruction of dangerous bacteria run a strictly parallel course either in septic tanks or in polluted rivers.

"It is also true that the mere number of bacteria in a water is no absolute criterion of the purity of the water. At the same time it must be admitted that the fate of typhoid bacilli introduced into a river is probably more closely correlated with that of other sewage bacteria than with oxidation changes in chemical constituents. The diminution in the numbers of bacteria in the Desplaines and Illinois rivers from Chicago to *Grafton is shown in Table III and graphically in Fig. 45.

*Grafton is situated at the junction of the Illinois and Mississippi rivers.

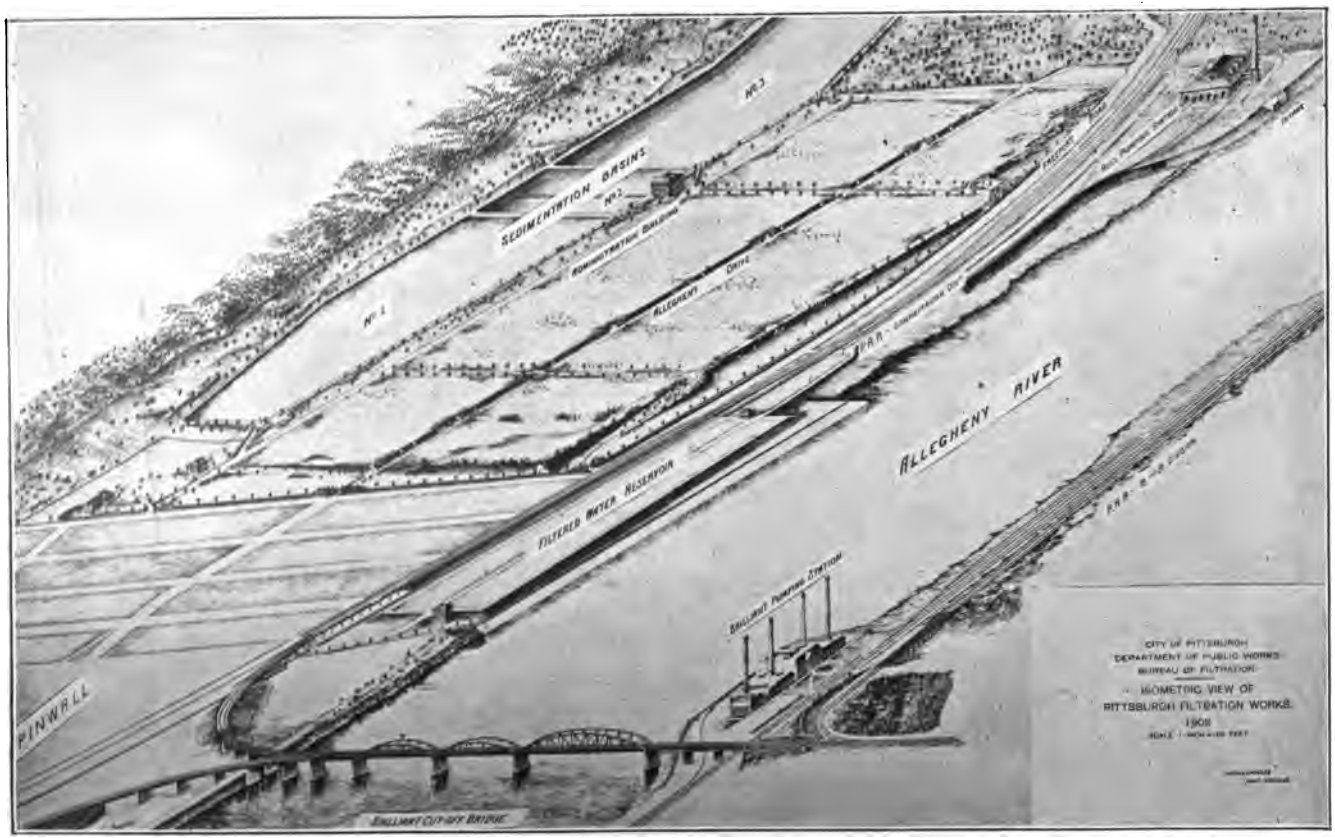


Fig. 46. Filtration Works of the City of Pittsburg.

"There is no reason to suppose that the typhoid bacillus is any more resistant than the average sewage bacteria, and the enormous reduction in the numbers of the latter shown in the table would seem to indicate a similarly high and speedy mortality among typhoid bacilli introduced into a flowing stream.

"Considered as a general proposition, the self-purification of streams has received more attention than its practical importance would appear to warrant. Under actual conditions implicit reliance on

Fig. 47. Birds-eye View of Sedimentation Basin under Construction, Showing Ross Pumping Station in the Distance.

the natural purification of a river water is usually misplaced. A stream may conceivably rid itself of infection, if such infection be introduced at only one point, but may, nevertheless, be so exposed to contamination at other points along its course as to be totally unfit as a source of public water supply. Efficient control over the water sheds of such streams as the Mississippi, Illinois, and Missouri is obviously quite impracticable. It is only under such very unusual conditions as exist along the lower Mississippi that a river has a chance to work out its own salvation. If continuous contamination be withheld for a certain number of miles, or rather days, then *self-*

Fig. 48. Introduction of Graded Gravel in Filter Beds.

Fig. 49. Interior of Filter Bed before the Admission of Sand and Gravel.

purification may become a factor worthy of consideration. Such a condition is evidently rare.

"The other extreme of opinion is equally untenable. Such an assertion as the following has been made, that 'water once polluted is unsafe for domestic use unless artificially purified.' No such sweeping statement can be justified unless based on a belief in the immortality of disease germs. All that we know about the bacteria of water-born diseases goes to prove that they never multiply in water even when this is highly polluted, that they die out rather rapidly, and that even the few more resistant individuals lose their virulence and do not long retain their power of producing infection."

The foregoing facts on the purification of water supply serve to show to what extent the typhoid death-rate can be controlled by proper sanitary precautions. In spite of these remarkable facts, there has been a noticeable slowness on the part of many communities in profiting by the lessons which they teach. Many towns and cities, especially in the United States, have remained unobservant and negligent as if they were waiting for some local demonstration which would cost many lives to prove to them that such precautionary measures are necessary. A method that has not only reduced the deaths from typhoid fever by about 75 per cent., but also has reduced the number of cases proportionally, is worthy of universal adoption. It is an admitted fact that if a new antitoxin were discovered which would reduce the fatality of typhoid fever from 12 per 100 cases to 3, the world would sound the praises of its discoverer; nevertheless, the fact that the introduction of a pure water supply has brought about quite as large a reduction in the death rate, and has conferred the added benefit of preventing the occurrence of a smaller proportion of cases, not only causes comparatively little interest but actual indifference on the part of the general public. On the other hand, a number of American municipalties have installed expensive filtration plants in an effort to obtain a pure water supply. The city of Pittsburg has installed such a system, some of the details of which are shown in Figs. 46, 47, 48, and 49.

Danger of Infection from Milk Supply. Of the many other vehicles of infectious disease there remains only one which seems to come within the scope of this article. It might be considered that *ice* should be treated as a more or less dangerous carrier of micro-

organisms, but it has been rather well proven that the scientific theory that *water purifies itself on freezing* still holds. Many analyses of natural ice have been made and the only condition which brings about any large degree of contamination is the case where the ice forms in such shallow water that it is impossible for the bacteria already present in the water to avoid being imprisoned in the ice.

When we come to the subject of *milk*, however, this important human food is found to be one of the most dangerous carriers of disease that we have. For a long time milk was looked upon with perfect security as being one of the natural foods which need give man no cause for worry; but in late years, while maintaining its reputation, even under the scrutiny of the chemist, as regards its food value, and its comparative cheapness, it has sadly lost caste with bacteriologists, and sufficient agitation has been developed to bring about tremendous changes in the care which this product receives in its passage from the cow to the human stomach. The main changes in the handling process have been in the care exercised in milking the cows, the requisite cleanliness to be observed, the bottling of the product soon after it is taken from the cow—or if some of the modern sterilizing processes are used, putting the milk in germ-free receptacles immediately after sterilization—and finally, the keeping of the milk at a comparative low temperature during the entire period.

The milk is usually tested to find the number of bacteria per cubic centimeter as follows: One c.c. of the milk is taken and diluted with about 100 c.c. of pure water; then 1 c.c. of this diluted liquid is mixed with sterilized gelatine and poured into a flat glass dish and covered, to await the growth of the culture. Each bacterium feeds upon the gelatine and forms its own colony, as shown by the round dots in Figs. 50 and 51. By counting these dots and multiplying by the dilution factor, the number of bacteria present in the milk is obtained. Evidently the sample shown in Fig. 50 is much more free from the germs than that of Fig. 51.

Professor H. L Russell, of the Wisconsin Experimental Station, cites in his little volume on *Dairy and Bacteriology*, an instructive experiment — as reported by Frankland in *Bacteria in Daily Life*—which shows the possibility of preventing the milk from becoming infected by its surroundings when taken from the cow.

"A cow pastured in a meadow was selected for the experiment,

and the milking was done out of doors, so as to eliminate as far as possible any intrusion of disturbing foreign factors into the experiment, such as the access of microbes from the air in the milking-shed. The cow was first partially milked without any precautions whatever being taken, and during the process a small glass dish containing a layer of sterile nutrient gelatine was exposed for one minute beneath the animal's body, in close proximity to the milk-pail. The milking was then interrupted, and before being resumed the udder and

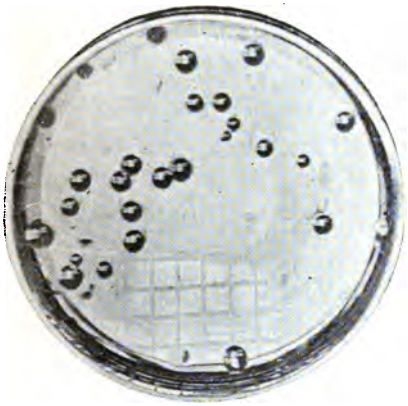


Fig. 50. Culture from Sample of Pure Milk (Heinemann).

Fig. 51. Culture from Sample of Ordinary Milk (Heinemann).

legs of the animal were thoroughly cleansed with water; a second gelatine surface was then exposed in the same place and for the same length of time. The results of these two experiments are very instructive. When the cow was milked without any special precaution being taken, 3,250 bacteria were deposited per minute on an area equal to the surface of a ten-inch milk-pail; after, however, the animal had been cleansed, only 115 bacteria were deposited per minute on the same area.

"Thus a large number of organisms can, by very simple precautions and very little extra trouble, be effectually prevented from obtaining access to milk. Even in the event of the milk being subsequently *pasteurized,* clean milking is of very great importance; but still more imperative is it when it is destined for consumption in its raw, uncooked condition. If we consider how cows become covered with dirt and slime, that obstinately adhere to them when

they wade through stagnant ponds and mud, and realize the chance thus afforded for malevolent microbes to exchange their unsavory surroundings for so satisfactory and nourishing a material as milk, then indeed precautions of cleanliness, however troublesome, will not appear superfluous.

"That a very real relationship does exist between the bacterial and dirt contents of milk has been clearly shown by actual investigation. A German scientist has made a special study of the subject, and has determined in a large number of milk samples the amount of foreign impurities present per litre, and the accompanying bacterial population per cubic centimeter.

"The following results may be taken as typical of those obtained: In milk containing 36.8 milligrammes of dirt per quart as many as 12,897,000 bacteria were present per cubic centimeter; in cleaner samples, with 20.7 milligrammes of dirt per quart, the number of bacteria fell to 7,079,820; whilst in a still more satisfactory sample, containing 5.2 milligrammes of dirt per quart, there were 3,338,775 bacteria per cubic centimeter.

"Such results indicate how important a factor is scrupulous cleanliness in milking operations in determining the initial purity of milk, for there is no doubt that bacterial impurities in milk are in the first instance, to a very great extent, controlled by the solid impurities present. . . . It follows as a natural sequence that all the cans and vessels used for dairy purposes should be absolutely beyond suspicion of contamination. Professor Russell has shown by actual experiment that, even where the vessels are in good condition and fairly well cleaned, the milk has a very different bacterial population when collected in them and in vessels *sterilized by steam.*

"Two covered cans were taken, one of which had been cleaned in the ordinary way, and the other sterilized by steam for half an hour. Previous to milking, the animal was carefully cleaned, and special precautions were taken to avoid raising dust, whilst the first milk, always rife with bacteria, was rejected. Directly after milking, bacterial gelatine-plates were respectively prepared from the milk in these two pails, with the following results: In one cubic centimeter of milk taken from the sterilized pail there were 165 bacteria; in that taken from the ordinary pail as many as 4,265 were found.

"Another experiment illustrates perhaps even more strikingly

the effect of cleanly operations in milking upon the initial bacterial content of milk. The preliminary precautionary measures were carried out by an ordinary workman, and are in no sense so refined as to be beyond the reach of ordinary daily practice. 'The milk was received in steamed pails, the udder of the animal, before milking, was thoroughly carded, and then moistened with water, so as to prevent dislodgment of dirt. Care was taken that the barn air was free from dust, and in milking, the first few streams of milk were rejected. The milk from a cow treated in this way contained 330

Fig. 52. A Cuban Milkman.

bacteria per cubic centimeter, while that of the mixed herd, taken under the usual conditions, contained 15,500 in the same volume. The experiment was repeated under winter conditions, at which time the mixed milk showed 7,600 bacteria per cubic centimeter, while the carefully secured milk only had 210 in the same volume. In each of these instances the milk secured with greater care remained sweet over twenty-four hours longer than the ordinary milk.' "

To illustrate the effect of temperature upon the ability of the bacteria already present in the milk to breed successfully, Table IV, taken from Jordan's *General Bacteriology*, is here presented.

When it is remembered that the minimum number of bacteria which is considered safe by the Board of Health is 500,000 in each cubic centimeter, and further that a temperature as low as 4 to 6°C.—equivalent to 38 to 42°F.—produces a great amount of sluggishness in the bacteria, it will be realized to what an enormous extent these active little organisms must multiply at a temperature considerably higher than these. The temperature of the milk in the goat-skin bags which the Cuban milkman has upon his horse, Fig. 52, must be highly conducive to bacterial breeding, to say nothing of the many other hygienic defficiencies shown in his outfit, and yet this picture represents a condition which can be seen to-day in almost any locality in Cuba. The figures given in Table IV are based upon the number of bacteria found in each cubic centimeter of milk.

TABLE IV

Showing Effect of Age and Temperature upon Bacteria Content per c.c. of Milk

Carefully Selected

Age	4°C. (38°F)	6°C. (43°F)
24 hrs.	2,500	3,100
48 "	3,600	12,000
96 "	218,000	1,500,000
108 "	4,209,000	80 millions

Ordinary

Age	4°C.	6°C.
24 hrs.	38,000	42,000
48 "	56,000	360,000
96 "	4.3 millions	12 millions
108 "	38 millions	300 millions

Several processes of treating milk to reduce the number of bacteria before it is supplied to the consumer have been devised. They can be only briefly mentioned here. The oldest and most natural one is that of *sterilization* by boiling. There is no question as to the efficacy of this process so far as the destruction of germ life goes but it has several important disadvantages in the fact of the change

in flavor due to the boiling, and in the alteration of the milk so as to make it less digestible, especially for infants. This disadvantage has led to a process known as *pasteurization*, so called in honor of Pasteur. This process consists in heating the milk to about 160 °F., which temperature is maintained for from 20 to 30 minutes, a sufficient time in which to kill all disease germs and most of the harmless germs which produce fermentation of the milk and yet produce only a slight alteration in the taste. The processes of producing condensed milk and cream and modified milk are hardly along the line of general milk supply and need not be discussed. Enough has been said, however, to show that attention must be directed with extreme care to the supplies of milk which are introduced in our homes and that this useful product is on a par with our water supply as a fertile source of disease.

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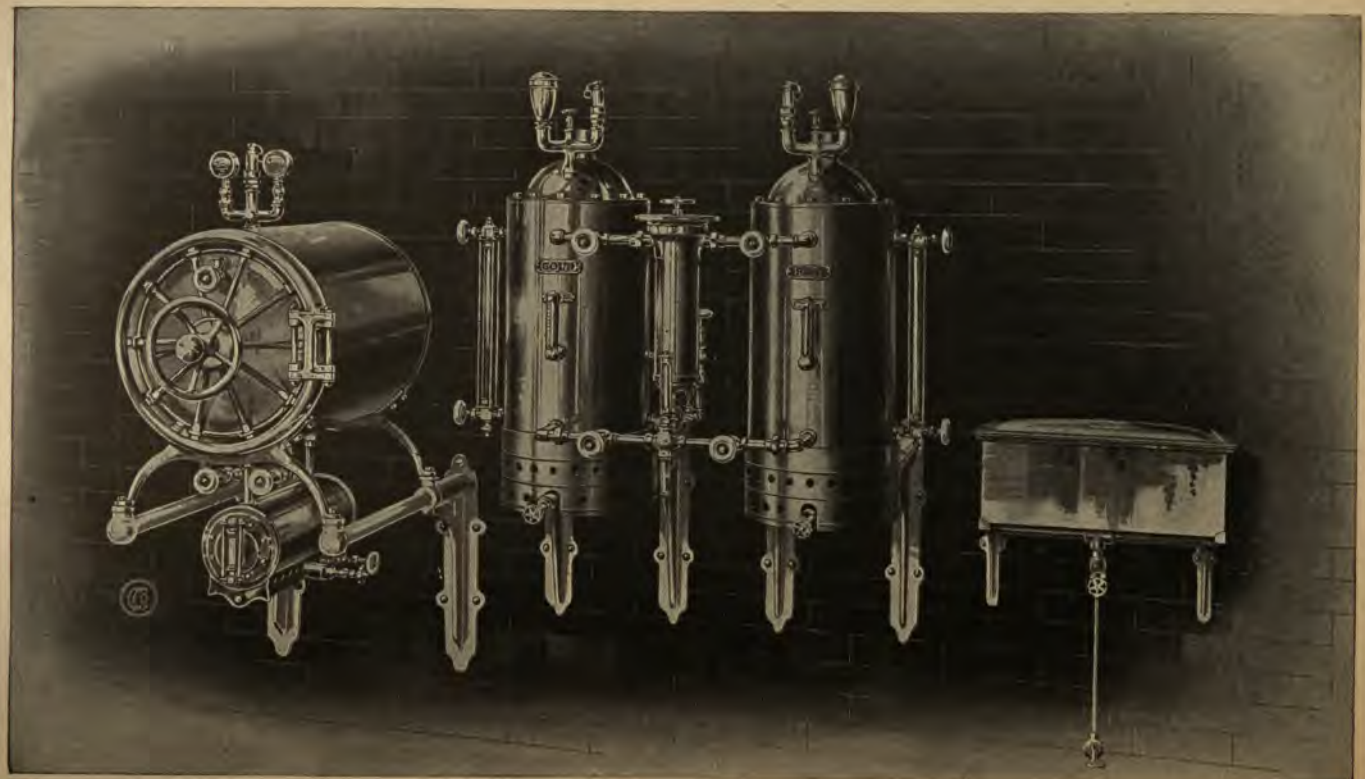
*The Author wishes to acknowledge having gathered his material largely from the following sources: Sedgewick's *Principles of Sanitary Science and Public Health* (Appleton); Frankland's *Bacteria in Daily Life* (Longmans, Green & Co.); Elliott's *Household Bacteriology* (American School of Home Economics); and Jordan's *General Bacteriology*—to which the student who designs to pursue further reading is referred. The bibliography of the subject of sanitation is particularly complete in Dr. Sedgewick's work. The Author also wishes to express his appreciation of the friendly assistance and advice of Professor Jordan and Dr. Heinemann of the University of Chicago.



BATTERY OF HIGH-PRESSURE STERILIZERS MOUNTED ON WALL BRACKETS

Courtesy of Crane and Nordway Company, Chicago

INFECTIOUS DISEASES DISINFECTANTS GARBAGE DISPOSAL

NATURE AND CAUSE OF INFECTIOUS DISEASE

GERM THEORY OF DISEASE

Recent Discovery of Germs. Checking the spread of infectious diseases is the most important of all the duties of a sanitary inspector. He is required to give notice to the health officer of the occurrence of any contagious or infectious diseases within his district. It is imperative, therefore, for him to acquire a thorough knowledge of the special precautions which must be taken to prevent the spread of disease and to detect the peculiar symptoms noticeable in persons afflicted with communicable diseases.

Fifty years ago, pathogenic organisms (disease-producing germs) had been scarcely heard of, yet today one cannot pick up a daily paper or a periodical without finding numerous references to them. This fact is, of course, principally due to the thorough understanding which we now have of these destroyers, but is in part the result of the long campaign of publicity which has certainly enlightened the public. Many people cannot believe a thing which they cannot see with the naked eye, and it is hard for them to realize that disease germs to the extent of 30,000 may be found on the legs of a small house fly.

General Character of Bacteria. Disease germs, indifferently spoken of as *microbes, micro-organisms, microzymes, bacteria,* or *contagia* are minute vegetable cells varying considerably in form, being either round, oval, rod-shaped, or spiral. Some of these germs are provided with lashing tails by which they move; others are without these appendages. Their size varies from about $\frac{1}{50000}$ to $\frac{1}{500}$ inch in length or breadth. They multiply usually by fission or division, while a few increase their kind by means of spores or eggs. They are difficult to kill and will resist nearly all

outside influences and will even withstand boiling for a very short time. Temperatures from 40° to 80° F. make them develop very rapidly and, under favorable conditions, a single bacterium can develop into sixteen millions in the course of a day.

Simple Nature of Disease. Diseases are caused and spread by a process resembling the sowing of seed on suitable soil, in which, by reproduction, the seed, in its turn, becomes a new center or focus of material whence it may spread and extend to others. A good example of this sequence of events is seen if we put a little yeast in a solution of sugar. Yeast consists of innumerable plant cells; when it is placed in the sugar, fermentation is set up, carbon dioxide is given off into the air, alcohol remains, and the yeast cells have increased enormously. Now substitute your body for the sugar and some pathogenic organism for the yeast, and at once you produce an infectious disease.

Definitions. *Infectious.* Any disease, like smallpox or measles, which is capable of being transmitted from one person to another without actual contact is termed infectious.

Contagion. Contagion denotes the transmission of an infectious disease, either through contact with the sick or with objects that have been in contact with the sick.

Contagious. Where direct contact between the sick and well is indispensable for the transmission of a disease, such a disease is termed contagious.

Infective. All infectious or contagious diseases and also diseases spread by inoculation are said to be infective.

Inoculation. By inoculation is meant the introduction of the virus of a disease into the body, either through or under the skin, a blood vessel, or an abraded surface. Malarial fever, for instance, is spread by the mosquito injecting its virus into the body.

Immunity. Immunity is the inherent ability of the body tissues to either destroy or neutralize the invading organisms. The natural resistance to the invasion of pathogenic organisms may be a family condition or simply an individual condition. One may be immune from infectious diseases by reason of having already had the disease or of being protected by inoculation of the virus in small doses. Furthermore, immunity from disease may

be destroyed or weakened by various modes of living, confinement in the house, or other causes conducive to lowering the vitality of the body.

Incubation. Incubation is the period which elapses between the contagion being taken into the body and the manifestation of the disease. In some cases this may be only two hours, while in others it may be three weeks.

Invasion. When the period of invasion is reached, the germs, which have been multiplying rapidly during the incubation period, manifest themselves in the symptoms peculiar to the disease.

Convalescence. The gradual recovery of health and strength after the contagion has left the person is known as the period of convalescence.

Quarantine. Quarantine is a period, originally forty days, of detention of ships and their passengers coming from a port where smallpox, yellow fever, or some other infectious disease prevails. It is also a place where passengers coming by ship from an infected port are detained until the incubation period of the disease has passed. At present, the term is applied to the prohibiting of persons from intercourse because of fear of infection. A quarantine flag is a yellow flag displayed by a ship to signify the presence on board of a contagious disease.

Isolation. Isolation means cutting off from or placing in a detached situation or, as applied to this subject, separating the sick from the healthy.

CHARACTERISTICS OF DISEASES

Smallpox, or Variola. When smallpox is present, all parts of the body and all secretions and excretions contain the contagium of the disease. The incubation period is usually twelve days but may vary slightly in some cases. The onset is rather sudden, and the patient usually suffers from shivering, pains in the head and back, and, occasionally, convulsions. About the third day, hard shoddy red spots appear and turn into blisters. These blisters fill with matter about the twelfth day, and the sufferer must be isolated until they disappear and the skin is quite clear again. The best way of combating smallpox is by vaccination. This procedure is practically that of inoculating the human being with

the lymph, or infection juice, of smallpox after it has passed through the body or blood of a calf, the result being the infection of the human body with a mild form of the disease, which, while giving rise to little or no physiological disturbance, renders the body more or less insusceptible to the true and original smallpox. As already mentioned, the incubation period of smallpox is twelve days, and the incubation for vaccination is only eight days, thus it is possible to prevent smallpox from developing if taken within three days after exposure to infection. Statistics prove that vaccinated persons are not so liable to contract the disease and therefore every child should be vaccinated. During an epidemic of smallpox, every person that has not been vaccinated within seven years of the outbreak should be revaccinated.

Scarlet Fever, or Scarlatina. The most common mode of infection with scarlet fever is by direct contact with an infected person, but it may be transmitted through milk or cream. This disease is most prevalent among children under four years of age and rapidly declines with increasing age. The incubation period varies from one to five days, and the patient has a hot burning skin and high fever. The head always aches, and vomiting may occur, but what is generally looked for in diagnosing this disease is a sore throat. Very small bright red spots appear on the chest, thighs, and back about the second day, and the disease must be considered infectious until the skin-peeling stage is over, which is from six to eight weeks.

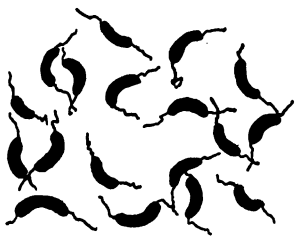


Fig. 1. Cholera Bacilli

Cholera. Cholera is a violent disease which commences with diarrhoea, violent pains, and purging. About the second day, the patient collapses and, generally, the features turn blue. If no improvement takes place at this stage, death will occur. In this disease the pathogenic organisms; Fig. 1, are contained in the stools, or evacuations, and in clothing or water fouled by them. Cholera is usually imported into this country.

Diphtheria. For a number of years it was thought that the accumulation of filth, defective drainage, etc., were the causes

of diphtheria, but about 1885 it was proved that such conditions only tend to lower the standard of health and render the person more susceptible to the diphtheretic bacillus. The disease commences gradually and the incubation period varies from two to seven days. The symptoms are weakness, loss of color and appetite, sore throat, and hoarseness. No rash appears, but small white specks and gray patches are to be found in the mouth and throat. It usually runs a course of eight or fourteen days, but the patient should be considered infectious for at least one month. Diphtheria has been robbed of a great deal of its danger since the introduction of the diphtheria antitoxin, but it is imperative that no time be lost in calling a physician. The germs greatly magnified are illustrated in Fig. 2.

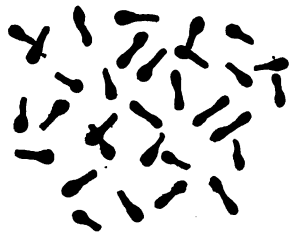


Fig. 2. Diphtheria Bacilli

Diarrhoea. Diarrhoea should certainly be classed as an infectious disease. Epidemics of this disease occur in large towns and crowded areas, especially if the garbage is removed by the conservancy method. Nearly every July and August an epidemic of diarrhoea breaks out, which is fatal to infants, among whom it produces a mortality rate of 25 per 1000 of births. The infection of milk at the farm, during transit, or by faulty storage in the home is perhaps the most common cause of epidemic diarrhoea; but foodstuffs are equally liable, especially where carelessness prevails as to cleanly and wholesome storage.

Dysentery. Dysentery is the term used for inflammation of the large intestines. There are two forms, acute and chronic. It is usually brought about by change of weather, errors in diet, bad hygiene, or impure water. Dysentery usually begins with diarrhoea and loss of appetite and this is followed by colicky pains in the abdomen, a burning sensation in the rectum with the feeling that there is an obstruction there and a constant desire to expel it. The stools are frequent, bloody, full of mucus and pus, and very fluid.

Measles. Measles is a very infectious disease and is spread by the air, clothing, handkerchiefs, bed clothing, etc. The infective germ is contained in the mucus of the nose, mouth, and throat

and in the breath. Owing to the early infectiveness of the disease, it spreads rapidly among school children, but the greatest fatality is in the second year of life. It commences gradually and is very infectious before as well as after the rash appears, which is usually on the fourth day. The symptoms are feverish cold, sneezing, and watering of the eyes and nose. The incubation period may be from ten to twelve days, and the rash is composed of dull red spots forming groups, first appearing on the face and neck. It must be considered infectious for about a month. Second attacks are very uncommon.

Typhoid Fever, or Enteric. Typhoid fever is invariably brought about by defective drains and impure water. It commences very gradually with weakness, loss of appetite, fever at night, and often diarrhoea. The incubation period is somewhat long, ranging from fourteen to twenty-one days. A few rose-colored spots first appear on the abdomen, coming in daily crops after the eighth day. The infection lasts from six to twelve weeks. All bowel discharges must be adequately disinfected for at least ten days after convalescence is reached; this also applies to cholera and diarrhoea. Typhoid bacteria with lashing tails are shown in Fig. 3.

Fig. 3. Typhoid Bacilli (with Flagella)

Typhus Fever. Typhus fever is not so prevalent now as in former years, and many physicians in the United States never have seen a case. It usually occurs in the poorest and dirtiest districts, where overcrowding is to be found. The infection is very much weakened by diffusion and dilution with pure air. While it may be transmitted by means of clothing, it is chiefly communicated by air at close quarters. The incubation period is twelve days, but the onset is very sudden and accompanied with headache, pains in the back and limbs, and a high temperature. Dirty pink spots appear grouped together in patches, but they disappear when subjected to pressure. The spots present themselves about the fifth day, and the disease lasts from three to six weeks. New light has been thrown on this disease within

the past year showing that typhus may be contracted through inoculation, the chief parasite producing the disease being the *acarus scabiei* (crab), Fig. 4.

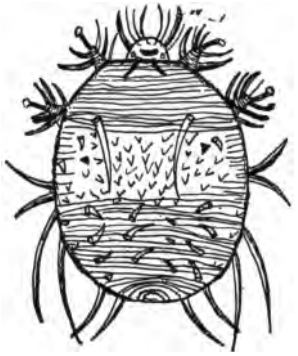


Fig. 4. Acarus Scabiei, Carrier of Typhus Fever

Tetanus, or Lockjaw. Tetanus is essentially a soil, or earth, poison disease. It is not infectious but commonly occurs as the result of inoculation or the fouling of wounds by dirt, mud, earth, or horse dung. The germs, Fig. 5, differ materially from those already shown.

Anthrax. Anthrax is a very fatal disease in animals, especially in cattle and sheep, and butchers may become infected with it when dressing a diseased carcass. Tanners and wool sorters may also inhale the germs when handling the hides or sorting the wool. The disease is marked by hemorrhage and symptoms of extreme prostration. Wool and hides that are suspected should be disinfected with steam. Anthrax bacilli, showing another variety of organism, are shown in Fig. 6.

Fig. 5. Tetanus Bacilli

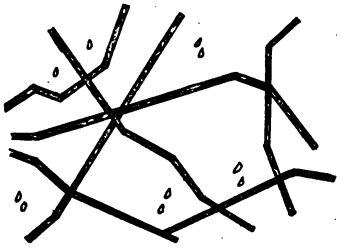


Fig. 6. Anthrax Bacilli

Grip, or Influenza. Grip must certainly be classed as an infectious disease. It is spread from one person to another by direct infection and is conveyed by the mucous discharge from the nose, throat, and lungs. Pocket handkerchiefs are responsible for the spreading of grip. The contents of the handkerchiefs dry, turn into dust, and, passing into the air, are inhaled by other persons. An infected person should remain in the house at least ten days. The symptoms are very well known, namely, headache,

sneezing, watering of the eyes, pains in every bone in the body, nervous disturbances, insomnia, mental depression, and often high fever.

Whooping Cough. Whooping cough is an acute infectious disease characterized by recurrent attacks of spasmodic coughing that continue until the breathing is exhausted and ending with deep noisy inhalations. The infection is given off in the secretions from the lungs. The organisms are not carried far into the air but cling to articles of clothing. The period of incubation may last from one to three weeks. The period of infection is usually not less than six weeks from the onset of the cough and may be longer. There were 9958 deaths from whooping cough in the United States in one year, yet parents look upon this infectious disease as unimportant and fail to take it seriously.

Relapsing Fever. Relapsing fever, sometimes called *famine*, or *recurrent fever*, closely resembles typhus fever. It is brought about by overcrowding and lack of food and is very infectious. It is carried in the clothing, etc., and runs a course of about six days.

Tuberculosis, or Phthisis, or Consumption. The "white plague", another name for this dread disease, consumption, is now occupying the minds of not only the medical profession and sanitarians but of the general public as well. The symptoms of tuberculosis are too well known to need describing here, but the precautions which should be taken by everyone suffering with the disease are as follows:

Fig. 7. Tuberculosis Bacilli

(1) Do not spit, except into proper receptacles; then destroy the contents when dry. The breath of afflicted persons is free from all infection.

(2) Use paper handkerchiefs for expectoration; if linen ones are used, they should be put in boiling water before the contents dry.

(3) Rooms should be cleaned with wet cloths and should not be dusted or swept.

(4) Abundant quantities of fresh air and sunlight should be admitted to all rooms.

The dreaded disease-spreading bacteria of tuberculosis are illustrated in Fig. 7.

Chicken Pox. Chicken pox is a very mild disease but is, without doubt, infectious. The eruptions appear on any part of the body without any previous sickness, being irregularly added to by fresh crops of vesicles and continuing four or five days. As in smallpox, the length of the period of its infectiveness depends on the falling off of the scales or crusts. The incubation period is about fourteen days, and a period of at least eighteen days should elapse after exposure to infection before allowing children to return to school or mingle with others. It is difficult to make a correct diagnosis between chicken pox and smallpox, and it is therefore very desirable to schedule it as an infectious disease and thus minimize the risks of cases of smallpox being mistaken for chicken pox.

Erysipelas. Erysipelas can be described as a fever with a spreading inflammation of the skin. It is prevalent the world over, but is chiefly met with in temperate climates. Erysipelas is an infectious disease and is likely to be contracted by the intemperate, the ill-nourished, and those who have had it before. It is commonly believed that there is a relationship between erysipelas, blood-poisoning, and child-bed fever, but our knowledge of the disease is very limited, and the true condition existing between these diseases is not known.

CHECKING CONTAGION BY DISINFECTANTS

Precautions against Spread of Contagion. The foregoing are the chief diseases which interest us and every one of them may be said to be preventable. Should any present themselves in a locality, we must consider it our bounden duty to push forward every possible precaution against the spreading of the disease.

Notification. One of the first and simplest precautions against the spreading of contagious disease is the immediate reporting to the health officer of every case of infectious disease. Everywhere, notification by law should be made compulsory on the part of the doctor attending the case and by whoever is in charge of the patient. On receipt of the notification, the health officer or

sanitary inspector has the power to enforce any measures that may seem necessary. The diseases that should be scheduled are smallpox, cholera, diphtheria, scarlet, enteric, and relapsing fevers, erysipelas, chicken pox, and typhus fever in some districts. Municipalities may include any other infectious disease from time to time if it is thought necessary.

Isolation. Isolation, to be of any use, needs to be thorough and complete. When infectious diseases occur in a house, the person infected must be completely separated from the rest of the household. This can easily be done in most large private houses, but it is almost impossible in apartment buildings, boarding houses, and the crowded dwellings of the poor, therefore, the only alternative is to remove the patient to a fever hospital where he or she will no longer be a source of danger to others but will receive more skilled attendance then could be obtained elsewhere.

Disinfectants and Disinfection. A short time ago, Dr. J. T. Walker, of New York, carried out a nation-wide campaign for disinfectant legislation. Surveying this field for eighteen months, Dr. Walker discovered that 25 per cent of the disinfectants now sold are "utterly useless" and over 25 per cent more possessed very little value and would not kill disease germs. This is not just a question of the manufacturers amassing a huge fortune fraudently, but thousands of lives are sacrificed every year because there is no law to prevent dirty water being bottled and sold as an efficient disinfectant. Again, the public is in a position of false security, firmly believing that all disease germs have been destroyed by the so-called disinfectant it has used. Still further, a physician may recommend a disinfectant on the manufacturer's word without stopping to test the germicidal value of the article recommended.

Definitions. The difference between a disinfectant, a deodorant, and an antiseptic is not generally known, so before proceeding further, we will define these terms.

Disinfectant. When we speak of a disinfectant, we mean some agent that will completely destroy the various microorganisms which are the cause of infective diseases. A bad disinfectant is worse than none at all for, as already mentioned, it

misleads people into believing that its proper precautions have been taken.

Deodorant. A deodorant is a substance which, by its powerful smell, will disguise a smell or odor but will not destroy infective germs. For example, tobacco smoke, eau de Cologne, or the burning of cork will hide an offensive smell, yet the germ, which is the objectionable feature, still remains alive and is likely to work great havoc.

Antiseptic. An antiseptic is a substance which prevents or retards putrefaction. It is much preferable to a deodorant, for it not only hides foul odors but prevents the growth or development of the pathogenic organisms.

Disinfection may be accomplished in three ways, namely, by fumigation, by the use of chemicals, and by applying heat.

FUMIGATION

Fumigation Methods Inefficient. Fumigation rarely succeeds in destroying infective germs, and too much importance is attached to this method of aerial disinfection. However, the indirect effect of the process is certainly good, especially if sulphur is used, for the smell created by the burning sulphur is so vile that the occupants of the building are compelled to open doors and windows, for a very long time, and allow an abundant supply of fresh air to flow freely into the building. It may be mentioned here that it is totally impossible to destroy infective germs floating in an occupied room without also killing the persons living in it; but as soon as the room is vacated we can insure the destruction of all micro-organisms by a combination of scrubbing and scraping,

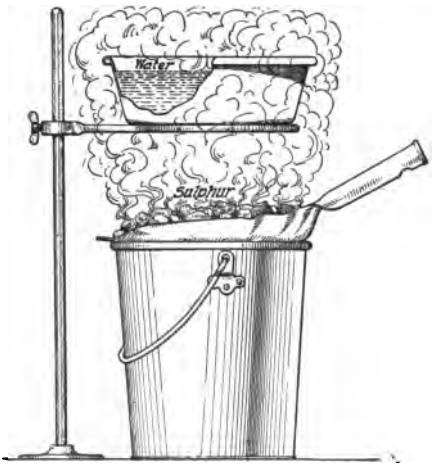


Fig. 8. Arrangement for Disinfecting with Sulphur

and spraying the ceiling, walls, and floors, etc., with an effective disinfectant.

Burning Sulphur. The oldest method of disinfecting by fumigation is carried out by burning, in a pan containing methylated spirits, 1½ pounds of sulphur to every 1000 cubic feet of air space. The gas given off is known as sulphur dioxide, or sulphurous acid gas. To help this gas to reach every part of the room and increase the disinfecting powers, a pail of hot water should be placed under and over the sulphur, as shown in Fig. 8, or, better still, the air in the room should be moistened with a steam spray. Sulphur candles, Fig. 9, are also used for disinfecting rooms. They should be placed on a plate or in a basin containing water as a protection against fire. With this method all gilt ornaments should be removed from the room and washed with a disinfectant, or they should be previously covered with grease.

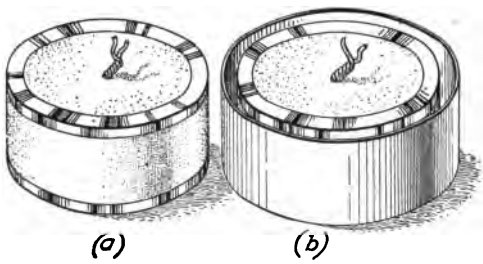


Fig. 9. Sulphur Candle (a) Separate, and (b) in Basin of Water

Chlorine Gas. A similar fumigation may be made by liberating chlorine gas. This gas is produced by moistening chloride of lime with sulphuric acid, or it may be made from black oxide of manganese with hydrochloric acid poured over it. As much as 15½ pounds of chloride of lime are required for every 1000 cubic feet of air space. As with the sulphur the air should be thoroughly moistened with a steam spray.

CHEMICALS

Strength of Chemicals Important. A much better method than the above is the spraying of rooms with suitable chemicals. It is absolutely imperative that the chemicals used be of the proper strength. The desired effect is the destruction of living organisms which consist of albuminous matter, and the object of the chemical is to penetrate their interior. If, however, the chemical solution be very strong, the exterior of the germ becomes coagulated and resists any further soaking into the substance of

the organism, so that practically no disinfection takes place, for the organisms are not killed but only temporarily put out of action. On the other hand, should the solution be too weak, it will not possess the necessary penetrating powers.

Formaldehyde. Formaldehyde may be used either in water solution and applied to walls and surfaces in the form of a spray or employed as a vapor. The commercial form of formaldehyde is formalin, which contains 40 per cent of formaldehyde. Formalin, 2 per cent, or 3 fluid ounces to 1 gallon of water, makes an efficient disinfectant. Special lamps are made for its use as a gaseous disinfectant. They have a small wick which burns methylated spirits under an iron receptacle open at the top. Formalin tablets are put into this receptacle—50 tablets for every 1000 cubic feet of air space—and the spirit lamp lighted under them, when formaldehyde gas is given off. This method is used for aerial fumigation, and all windows, chimney flues, ventilators, etc., must be kept closed and made perfectly air tight. The furniture, bedding, etc., must be so placed about the room as to insure adequate exposure to the fumes given off. This method is not nearly so effective, however, as spraying the walls, etc., with a small hand pump having a long nozzle containing fine perforations and using a 2 per cent formalin solution.

Corrosive Sublimate, or Bichloride of Mercury, or Mercuric Chloride. Corrosive sublimate, when used in the required strength, forms a powerful disinfectant. It is colorless and very poisonous and therefore should be colored blue to avoid accidents. About 3 ounces to a bucket of water makes the best known disinfectant for sewers and drains but must be used stronger for the stools of infected persons. A strength of 1 in 500 to 1 in 1000 is recommended. It destroys bedding, clothing, and metal goods. For the sake of convenience, it is made in the form of tablets which can be dissolved in water to make solutions of certain strengths, but they should only be given into practiced hands.

Green Copperas, or Sulphate of Iron. Green copperas may be used instead of corrosive sublimate for flushing sewers and drains or for spraying any offensive accumulations. About ½ pound to 1 gallon of water is used for drains, but for the stools of infected persons, etc., the proportion should be about 2 pounds to 1 gallon of water.

Chloride of Lime, or Bleaching Powder. Chloride of lime is a poisonous white powder which must be kept dry until it is required for use. A standard solution is made by dissolving 6 ounces of chloride of lime in 1 gallon of water. It is chiefly used for washing walls, etc., but should not be used in dairies, as the milk will become tainted with the smell.

Permanganate of Potash. Permanganate of potash is obtained in crystals and is easily soluble in water, turning the latter to a deep red. When organic matter comes in contact with it, the solution turns brown and is rendered useless. To be effective, it must be used in the strength of 5 per cent, or 1 ounce to 1 pint of water, and as this strength stains any article a deep brown color, it is impracticable for many purposes.

Izal. Izal is cream-colored emulsion which readily mixes with water, has strong disinfecting powers, and is nonpoisonous and nonvolatile. It is used in strengths of 1 part in 200, or 1 tablespoonful to 5 pints of water.

Nitrous Acid. Nitrous acid is a very powerful oxidizing and disinfecting agent. It is a very irritating gas and is readily evolved by placing a piece of copper in some nitric acid and water. Three ounces of nitric acid should be mixed with 3 ounces of water and poured on to one ounce of copper shavings contained in a jar. This forms à useful disinfectant in case of emergency but cannot be considered an ideal one.

Carbolic Acid. Carbolic acid is a strong caustic poison. When pure, it exists in the form of white crystals, but, if heated it liquefies, and should one-tenth of its volume of water be added, it will remain a liquid. It must be used in a strength of 1 part in 20 and is somewhat expensive if used in large quantities. It is a very poor disinfectant and will not destroy the spores of anthrax even after days of exposure. Spores placed in crevices of boards and freely disinfected with a 5 per cent solution for several days will not be affected.

Chloro-Naphtholeum and Pyro. The West Disinfection Company, of New York, manufacture and guarantee chloro-naphtholeum and pyro as disinfectants. Chloro-naphtholeum is a brownish liquid of a pleasant aromatic odor, derived from tar creosote, mixable in all proportions with water, forming a milk-white emul-

sion. It is guaranteed to be five times as strong as carbolic acid and forms a most efficient disinfectant for nearly all purposes if used in strengths of 1 in 100. It can also be obtained in the form of a powder. Pyro is very similar to chloro-naphtholeum but is less expensive. A strong solution must be used to produce the desired results.

Natural Disinfectants. *Earth.* The upper layers of earth, when dry, act as a strong disinfectant owing to the presence of nitrifying organisms that are able to render decaying matter harmless by a process of oxidation.

Light. Direct sunlight, even in winter, has been shown to be a powerful disinfectant.

HEAT

Heat may be employed in five different ways as a disinfectant, namely, by boiling; by burning; by dry hot air; by superheated steam; and by saturated steam.

Boiling. Boiling kills most pathogenic organisms if it is prolonged for ten minutes. Nothing beyond this is required for any infected articles.

Burning. Destruction by fire is, without doubt, the safest and best method of disposing of all articles of little value, such as old clothes, toys, bedding, etc. For large articles, a garbage destructor is the best means of disposal.

Dry Hot Air. Up to a few years ago, infected articles were disinfected in large ovens, but the heat penetrated very slowly into such articles as bedding, and many articles were scorched and damaged by the high temperature required. The only advantage it possesses is that leather goods and books are less likely to be damaged by it than by steam.

Steam. Steam, when employed as a disinfectant, may be either superheated or saturated—that is, close to the temperature at which it condenses. The following physical facts must be borne in mind:

(1) The boiling point of water, and consequently the temperature, varies with the pressure to which it is subjected.

(2) Water in passing from its liquid form into steam absorbs heat. This *latent heat* as it is called, is given out when the steam is condensed into water.

(3) Under pressure, steam may be heated considerably above the boiling point of water, viz, 212° F., when it is called *superheated steam.*

(4) Steam under ordinary atmospheric pressure becomes condensed on coming in contact with a comparatively cold object. This is saturated steam.

(5) Superheated steam on coming in contact with a cold object may be reduced in temperature but not sufficiently to make it condense and give up its latent heat.

Superheated Steam. Superheated steam may be produced in disinfectors in two ways: by providing a jacket around the disin-

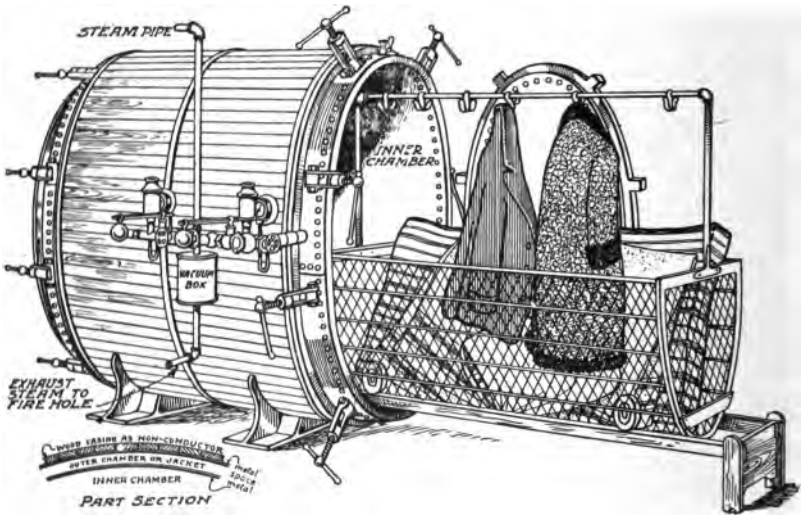


Fig. 10. Sketch of Lyon's Patent Steam Disinfector

fector, which is kept at double the pressure and at about 30 degrees hotter than the interior of the disinfector, Fig. 10; and by having a jacket containing a solution of calcium chloride or similar substance which is heated by fire under the disinfector. This solution should be kept at a fixed strength by automatic means.

Saturated Steam. Saturated steam is not under pressure and is admitted to the disinfector at a temperature of 212° F., with the result that it immediately condenses on coming in contact with the articles in the disinfector. This condensation causes an enormous shrinkage in its bulk, and its latent heat is evolved at

the same time. More steam is thus sucked into the vacuum formed, and this process is repeated over and over again until equality of temperature is reached in every part of the infected article placed in the disinfector, condensation ceases, and the infective organisms are totally destroyed.

PRECAUTIONS DURING OR AFTER CONTAGIOUS SICKNESS

The following simple instructions, if properly complied with, will effectually prevent infection from the disease.

General. Burn everything that can be burned; boil everything that can be boiled; wash and scrub well everything that can be scrubbed and expose to fresh air and sunlight. Send woolen articles, mattresses, etc., to be disinfected by steam to professional disinfectors.

Rule 1. Persons. The hands of those attending the infectious sick should be washed frequently and thoroughly with hot water and soap. If soiled or possibly infected with discharge, etc., they should be dipped in a solution of corrosive sublimate (1 in 1000). Gloves which have been worn must be burned. For washing the body of the infected person, a bath of corrosive sublimate (8 in 2000) should be used in the first instance, followed by a bath with soap and water. Dioxygen—oxygen combined with water—makes an excellent mouth wash; one teaspoonful to a glass of water will be almost too strong for this purpose.

Rule 2. Bedding. Small articles may be boiled for an hour or so, but bulky articles, such as blankets, mattresses, etc., should be subjected to moist heat in a proper disinfecting apparatus. Should no professional disinfector be at hand, these articles should be steeped in formalin (2 per cent), chloro-naphtholeum (1 in 100), corrosive sublimate (1 in 1000), or izal (1 in 20), for about 12 hours, then boiled and washed.

Rule 3. Discharges. The treatment of discharges is very important. All stools should be received in bedpans containing a 5 per cent solution of carbolic acid or a 5 per cent solution of chloride of lime. If corrosive sublimate is used, the solution should be 1 in 500. It should be left standing for an hour, when possible, but this is hardly practicable in the majority of cases.

Urine and vomit must be treated in exactly the same manner as the stools of infected persons. In case of scarlet fever, it is well to carefully oil the skin with vaseline or oil.

Rule 4. Furniture. Furniture may be washed with a solution of corrosive sublimate (1 in 1000) or, if upholstered, it may be saturated with the solution and dried. This will not hurt any material if no coloring matter is added to it.

Rule 5. Drains, Traps, and Garbage. The actual disinfection of drains and other places which receive offensive matter is impossible; the most that can be done is to deodorize them. This may be done by chemical reagents, such as lime, quicklime, and chloride of lime. Green copperas is a valuable agent for trap deodorization. It should be used in strengths of 1 pound of copperas to 1 gallon of water.

Rule 6. Sick Rooms. It has already been explained that spraying the walls with formalin (1 in 40) is the best method of disinfecting a sick room, but it should be remembered that walls should be sprayed from below upward to prevent streaks and discoloration. After cases of diphtheria the walls may be well scrubbed down with stale bread crumbs. Of course the crumbs must be burned afterward. Fresh air, sunlight, and washing with soap and water must be taken as a secondary precaution.

Rule 7. Shoes, Furs, Etc. If shoes, furs, etc., are of little value, burn them. If they are valuable, do not use steam disinfection as this would probably destroy them; they should be sprayed with formalin (1 in 40). Shoes should be completely filled with the above solution.

Rule 8. Floors. Floors should be washed with a solution of formalin (1 in 40), or corrosive sublimate (1 in 1000), and then with soap and water. Special care must be taken to allow the disinfectant to penetrate between the joints of the floor boards. During the occupancy of the sick room, tea leaves or sawdust saturated with the above solutions should be scattered freely about the floor.

Rule 9. Books. Books are very difficult to disinfect without damage to them. Books of little value should be burned, for steam damages them and dry heat can hardly be considered efficient. About the best known method is to stand the books on

end in closed chambers and expose them to formaldehyde vapors for about one hour.

Rule 10. Ships. Infected ships should have the bilge water pumped out and the bilge washed thoroughly with sea water. The inhabited parts of the ship should be sprayed with formalin or corrosive sublimate. All the water tanks should be emptied and refilled, for it must be remembered that water is a great absorber of gases.

Rule 11. Dead Bodies. The body of one who has died of an infectious disease, such as small pox, cholera, etc., should be washed with corrosive sublimate (1 in 500) and then enveloped in a sheet saturated with the same solution. In such cases, however, cremation is advisable.

Rule 12. Watering Streets. In dry weather a weak solution of permanganate of potash is cheap and useful as a deodorant to remove unpleasant odors. During an epidemic of any infectious disease, the streets should be watered with a solution of corrosive sublimate (1 in 2000).

GARBAGE COLLECTION AND DISPOSAL

Scavenging. The word "scavenge" is derived from a root signifying "to sweep", and originally the business of scavenging was almost altogether confined to street cleaning, as it was the custom to throw all garbage into the streets. At the present time scavenging has a much wider meaning and includes the scavenging and cleansing of streets, with the collection and removal of street sweepings and gully deposits and their ultimate disposal, and the removal and disposal of excretion from the pail, privy, cesspool, or midden.

Classes of Garbage. Before proceeding further, let us see what garbage is really composed of, as there are countless people who imagine it to be purely excremental matter and quite overlook the broken bottles, waste paper, vegetable matter, etc. Garbage may be divided into three distinct classes: *House garbage*, which includes ashes, cinders, rubbish, night soil, and filth but does not include trade garbage; *trade garbage* which is the refuse from any trade, manufacture, or business, or from any

building materials; and *street garbage,* which consists of dust, dirt, rubbish, mud and scrapings, snow, and filth.

Dumps and ashpits include any dump, ashpit, dustbin, ash-tub, or any receptacle for the deposit of ashes or garbage.

HOUSE GARBAGE

Classes of House Garbage. House garbage is the only kind of garbage which need receive our particular attention, for the other work is ordinarily taken in hand by the municipal engineer. House garbage is divided into three classes: (1) dry ashes, dust, food scraps, waste paper, tins, bottles, etc.; (2) excretal, liquid and solid excretal matter from humans and animals; (3) waste water from bathing, cooking, washing, etc.

Removal and Storage. In dealing with the removal of house garbage, it is imperative to learn thoroughly the chief items which must be carried out to insure success, namely, the garbage, if possible should be removed at once; it should be removed without causing a nuisance; if not practicable to remove at once, it should be retained as short a time as possible; and it should be so kept as to avoid fermentation and putrefaction.

There are two distinct methods of removing house garbage, viz, the conservancy, or dry system; and the water-carriage system. The conservancy system is so brimful of disadvantages, and the advantages of the water-carriage system are so evident, that the former method will be mentioned only on account of its historic interest, although in small towns this is still much used.

CONSERVANCY, OR DRY SYSTEM

Objections to Conservancy System. The objections to the conservancy system may be summarized as follows: The odor is offensive to the senses; the excretal matter is stored up near the dwelling; the removal of the garbage is degrading to the men who do the work and is also a nuisance; the matter is difficult to dispose of, is expensive, and is liable to pollute water, air, and soil.

ASHPITS OR DUMPS

Objections to Fixed Ashpits or Dumps. Some of the many objections to the fixed ashpits or dumps are that they are placed in unfavorable places and are often unsightly; they are likely to

have slop thrown into them and, as a consequence, the contents putrefy and often soak into and around the house; the pits are not emptied as frequently as they should be, and often a nuisance is created in the emptying process; however, they hold more garbage than the dustbin.

Construction of Dumps and Privies. All dumps and privies should be constructed in accordance with the following regulations:

(1) They must not be constructed within 6 feet of any dwelling.

(2) They must be 60 to 100 feet from any domestic water supply.

(3) They must have ready means of access for the purpose of cleansing and must be situated so that the contents need not be carried through any dwelling house.

(4) They must be provided with proper ventilation.

(5) The floor should be 6 inches higher than ground level, with a fall to the door of not less than ½ inch to 1 foot, and should be paved with some nonabsorbent material.

(6) If the *receptacle for the excretal matter is moveable,* there must be constructed over the whole area of the surface, immediately beneath the seat of the privy, a flag or an asphalt floor, at a height of not less than 3 inches above the level of the surface of the adjoining ground, and the whole extent of each side of such space between the floor and the seat must be constructed of flagging, slate, or good brickwork, at least 9 inches thick and rendered in good cement or asphalt. The seat, the aperture therein, and the space beneath must be of such dimensions as to admit of a moveable receptacle for filth, not exceeding 2 cubic feet in capacity, being placed and fitted beneath the seat in such a manner and position as to prevent the deposit of filth elsewhere than in the receptacle, and the seat must be so constructed that the whole or a sufficient part of it may readily be removed or adjusted to afford adequate access to the space beneath for the purpose of cleansing and removing the receptacle. Where the *receptacle is a fixed one,* the capacity must not exceed 8 cubic feet, and suitable means must be provided in connection with the privy for the application of ashes, dust, etc., to the excreta. There must be no leakage of water into the receptacle. It must be built in such a

manner and of such materials as to prevent the absorption or the escape of any of the filth deposited in it. The floor must be 2 inches above the ground level and there must be free access for cleansing.

Size and Structure of Ashpits. Ashpits should not exceed 6 cubic feet in capacity and should not be capable of holding more than one week's supply. The walls and floor of an ashpit should be impervious and the floor should be 3 inches above ground level. The whole should be well ventilated and should have a roof and also doors for the purpose of emptying as shown in Fig. 11.

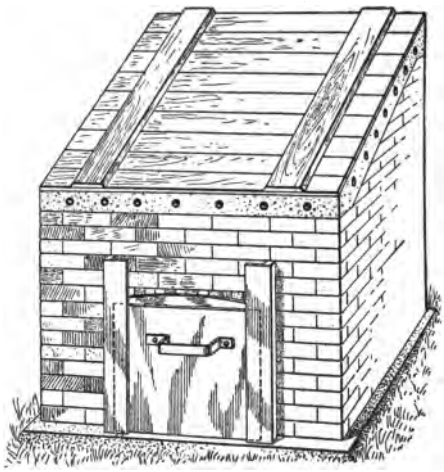


Fig. 11. Typical Ashpit

Pail System. Towns that have adopted the pail system have found that it possesses the following disadvantages: Soil is often polluted because the pail does not fit exactly under the seat, the contents are frequently spilled during removal, and the pail often leaks after a few months usage; it is a difficult and costly job to clean the pails; the pails give off offensive odors when in the closet; very often a difficulty presents itself in disposing of the contents; the carts removing the contents give off foul gases in the streets through which they pass; and sometimes the pails are constructed of wood and absorb filth.

Dry-Earth System. Another conservancy method is the dry-earth system. About the best type of earth closet procurable is shown in Fig. 12. It consists of a seat, above and behind which is a hopper containing a sufficient quantity of soil to last for some time. Connected with this is a valve, into which the earth falls, which is worked by either a handle or a lever connected with the seat. The soil resting on the valve is distributed on the excreta, and when the plug is pressed down or the seat is

used the valve is recharged. About 1½ pints of earth should be applied each time the closet is used. The earth must be finely sifted, and it is absolutely necessary to success to exclude all moisture except that contributed by the excreta and urine. The chief objection of this class of closet is that it must be fixed outside the house and requires a great deal of attention.

Cesspools. Before leaving this class of work, it will be advisable to consider the cesspool. Cesspools are often associated with the conservancy method. They may be described as underground receptacles to receive liquid and solid excretal matter. The construction of the cesspool is usually carried out as follows: A circular pit of the required size, with the bottom composed of cement concrete, is dug in the ground. The sides must be of good hard impervious brick, with cement joints. White glazed bricks are very suitable, but if soft bricks are used, the interior must be rendered in cement applied in two coatings. Obviously, this is not necessary when impervious bricks are used. The cess-pool should have a 9-inch backing of well-puddled clay and should be at least 50 feet from the dwelling and 100 feet from any water supply. It must be provided with a manhole cover at least 16 inches in diameter, while the escape of air is provided for with a single pipe carried up a tree or any convenient position to a height of 10 feet. The cesspool is provided with an overflow placed at a slightly lower level than the intake. This discharges into a stream, if one is at hand, or into a leaching cesspool or soak-away.

Fig. 12. Self-Acting Earth Closet

WATER-CARRIAGE SYSTEM

Advantages of Water-Carriage System. Take, now, the advantages that may be derived from the adoption of the water-carriage system. In this method, the excremental matter is removed at once from the house to a distance, thus avoiding the pollution of the water, air, and soil; it is very economical; and the unsightly, indecent, uncleansible privies are discarded and the water closets are fixed inside the house.

Dustbins for Dry Garbage. The dry garbage is best collected in a portable dustbin with a proper lid or cover to keep the contents dry and to avoid fermentation and putrefaction. They are best constructed of some impermeable material, such as galvanized iron, and can be placed in any position. Of course, we must always endeavor to place them in a position where they will not cause offense. These dustbins are easily carried to and from the scavenger's cart and can be emptied frequently. They are inexpensive and most economical to clean out.

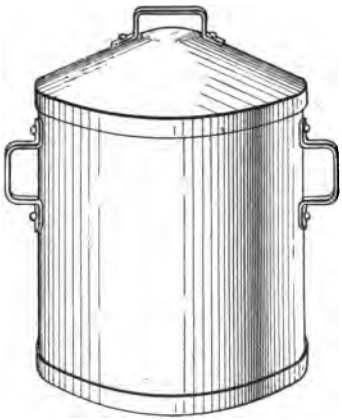


Fig. 13. Portable Dustbin of Galvanized Iron

It may be mentioned that in many towns municipalities provide portable dustbins free of charge, while in others the owner of the property must provide them. Portable dustbins must not be too large. A very convenient size is 20 inches high by 18 inches in diameter, giving a capacity of two cubic feet. This size, as shown in Fig. 13, insures their being emptied frequently.

COLLECTION OF GARBAGE

Quantity of Garbage. The quantities of garbage to be stored, collected, and destroyed vary considerably in different localities, but 500 pounds per head per annum with the water-carriage system may be taken as an average throughout the United States, and it is only natural that this quantity may be more than doubled with the conservancy system. The average with this

method may be taken at one-half ton per head per annum. The weight of garbage may be taken on the average as 1300 pounds per one cubic yard. A load by which garbage is often estimated varies in weight from 1300 to 3000 pounds.

Collection Methods. The collection of garbage is often let out to contractors but is more satisfactorily carried out by the sanitary authorities.

District Using Water-Carriage System. The removal of garbage in a water-carriage district is not a very difficult matter, for, as a rule, the garbage consists simply of cinders, waste paper, old crockery, and other dry substances which should be stored in a portable dustbin provided with a tight cover to exclude moisture. Some of the methods in use for removing the contents of these bins are as follows:

(1) By a house-to-house call at intermittent periods. This may be said to be the best method, but it must be borne in mind that the bins are only 2 cubic feet in capacity, therefore they should be emptied at least twice a week, and certain establishments require a daily call. If the house-to-house method is adopted, it is always advisable to arrange for the collection to take place between 12 P.M. and 6 A.M. The carts used for this purpose are built low upon their axles and consist of iron bodies upon wooden frames and wheels. They should be entirely covered with a removable lid.

(2) By the scavengers giving notice of their approach by ringing a bell or by other signals and requiring the householder to bring the garbage to the cart. This system is bad, as the occupants of houses often allow accumulations to occur that they cannot convey to the carts which, as may be surmised, often cause unpleasantness, to say nothing of the vile conditions from a sanitary standpoint. Again, this work has to be done during the day, and it is very disagreeable to have the carts lumbering through the streets full of offensive garbage.

(3) By placing dustbins in various places and expecting householders to discharge the house garbage into same. These are cleared from time to time by the sanitary authorities. All the disadvantages in the second method crop up here, and we can picture the rag and bone gatherer sorting the garbage in these

bins to see if there is anything of value to him. Again, dogs and cats scramble among the garbage for fish and bones, and lastly, it is not uncommon to see a group of children playing around a bin and inhaling the offensive gases given off from the decomposing matter.

District Using Conservancy System. In the conservancy system it is practically compulsory to remove the excreta and garbage by night. In small districts of a scattered nature, the farmers usually remove the garbage and dig it into the land, but there is always the danger of overstorage, for unless the householders pay a fee for the removal of the garbage the farmer will remove it only at his own convenience.

District Using Pail System. With the pail system, the pails as well as the contents should be removed on a rolley, and they should be thoroughly cleansed and disinfected before being returned. The pails should be numbered or lettered to avoid confusion and should contain some material to absorb the liquid and deodorize the excremental matter. Another system seeks the same object by lining the pails with waste material from woolen or cotton mills and also with chopped straw.

The water-carriage system by which all excremental wastes are at once carried away by drains and sewers is now regarded as the best, in fact, the only method that can be adopted for large and moderate size towns. In nearly all towns where the conservancy method is in use, its entire abandonment is either in contemplation or in progress in favor of the installation of a proper water-carriage system.

GARBAGE DISPOSAL

Nature of Problem. We have now dealt with the different types of garbage and the methods of storage and removal, but we have yet to consider the somewhat difficult task of its ultimate disposal. It may be mentioned here that with the water-carriage system the only garbage is that which is collected in the dustbin, and it is not very difficult to dispose of this.

Excretal Matter by Conservancy System. The disposing of excretal matter by the conservancy method causes endless trouble. In some districts it is sent out to sea in hoppers, and should the

currents of the sea be such as to keep it from washing up on the foreshore, the difficulty is ended. However, all towns do not have a sea at hand and other means must be found to get rid of their garbage.

In inland towns where the garbage is practically all excremental matter, the farmer will take it away and utilize it on the land, in a few cases paying for the privilege. In some places it is mixed with lime or any other suitable material and sold as

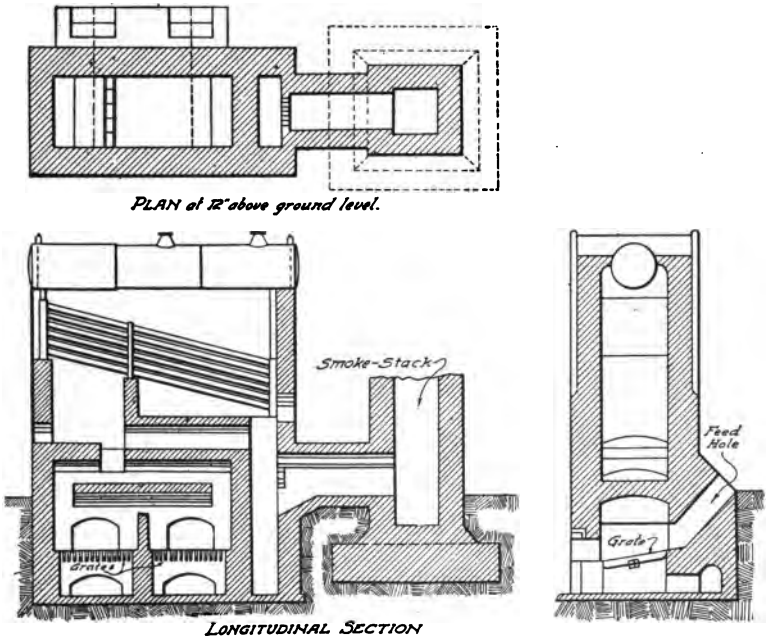


Fig. 14. Type of Incinerator Plant Used in the United States

manure, but there is no great demand for it, otherwise this method would be generally adopted, especially if it showed a small margin of profit. Again, it may be mixed with sewage slush and sold or given away as manure. This method is often adopted where both the conservancy and the water-carriage system are in force. The very objectionable method of filling in waste land with garbage should be looked upon as a crime and the culprits should be prosecuted.

Garbage where Water-Carriage Is System. Where there is little or no excremental matter, the garbage should in every case be

destroyed by fire in a furnace known as a *destructor, cremator,* or *incinerator.* Almost all authorities are now agreed that the burning of garbage is the best plan, for experience has taught them that the burning of garbage in furnaces is practicable; that there is no accumulation of offensive materials at the works and practically no smell; that everything combustible is burned within a

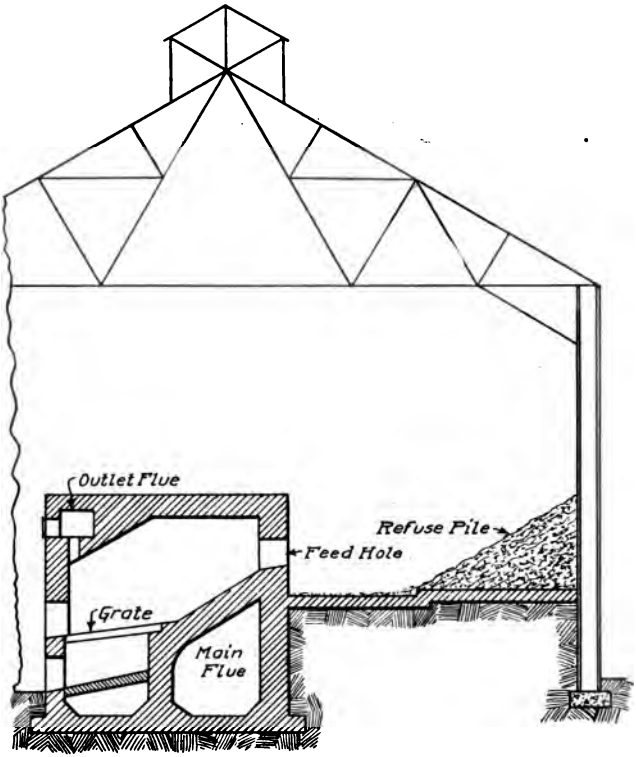


Fig. 15. Type of Incinerator Used in Russia

few hours and the cost is not excessive; and that burning provides a means of disposing of infected bedding, clothing, etc., and the carcasses of animals.

Types of Destructors. Destructors, with a few exceptions, have this common feature. The furnaces or cells are strongly built of bricks, with iron fittings, and the building surrounding and covering the destructor is of brick with a roof supported on iron columns. The destructor is approached by an inclined road-

way to the top of the tipping platform, from 16 to 18 feet above the clinkering floor, or ground level. In the center of the platform is a series of feeding holes, or hoppers, into which the garbage is thrown and let down into the furnace or cells below. The stokers standing on the clinkering floor, or ground level, rake the garbage forward on the grate or firebars, and once combustion is begun, no fuel is required, there being sufficient combustible

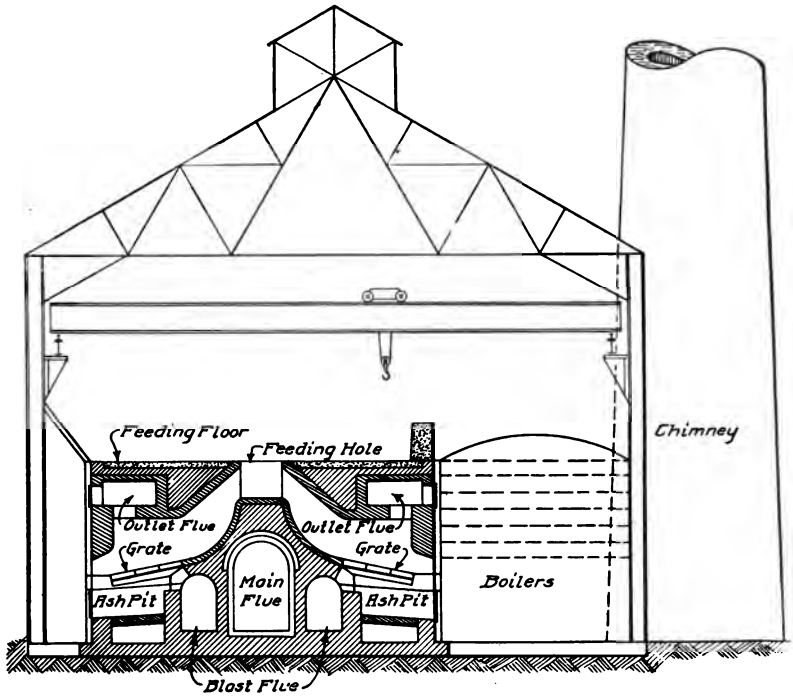


Fig. 16. Type of Incinerator Used in Egypt

matter in the garbage to keep the furnace going. There is no storing of garbage, since no more is taken to the destructor than can be burned at once. Figs. 14, 15, 16, and 17 show types of incinerators installed in different countries, yet all similar in the main. A destructor must be capable of destroying everything, producing in the chimney nothing but harmless gases, and nothing from the clinkering floor but perfectly burned and nitrous clinkers and ashes. To accomplish this the following requirements are necessary:

(1) Very high temperatures produced by forced draft, not less than 1300° F. The forced draft may be produced by either dry air or steam jets. It should not be less than 2000 cubic feet of air per minute per cell. Some makers design a fan to give 8000 cubic feet of air per minute per cell. One pound of coal requires

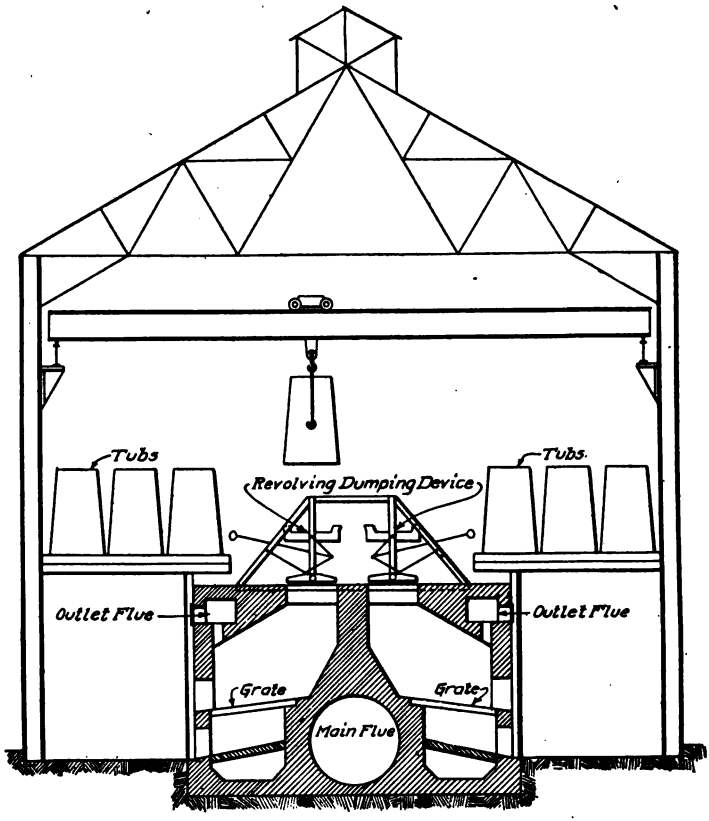


Fig. 17. Type of Incinerator Used in England

240 cubic feet of air to insure complete combustion, so some idea of the amount of air required to burn garbage can be formed.

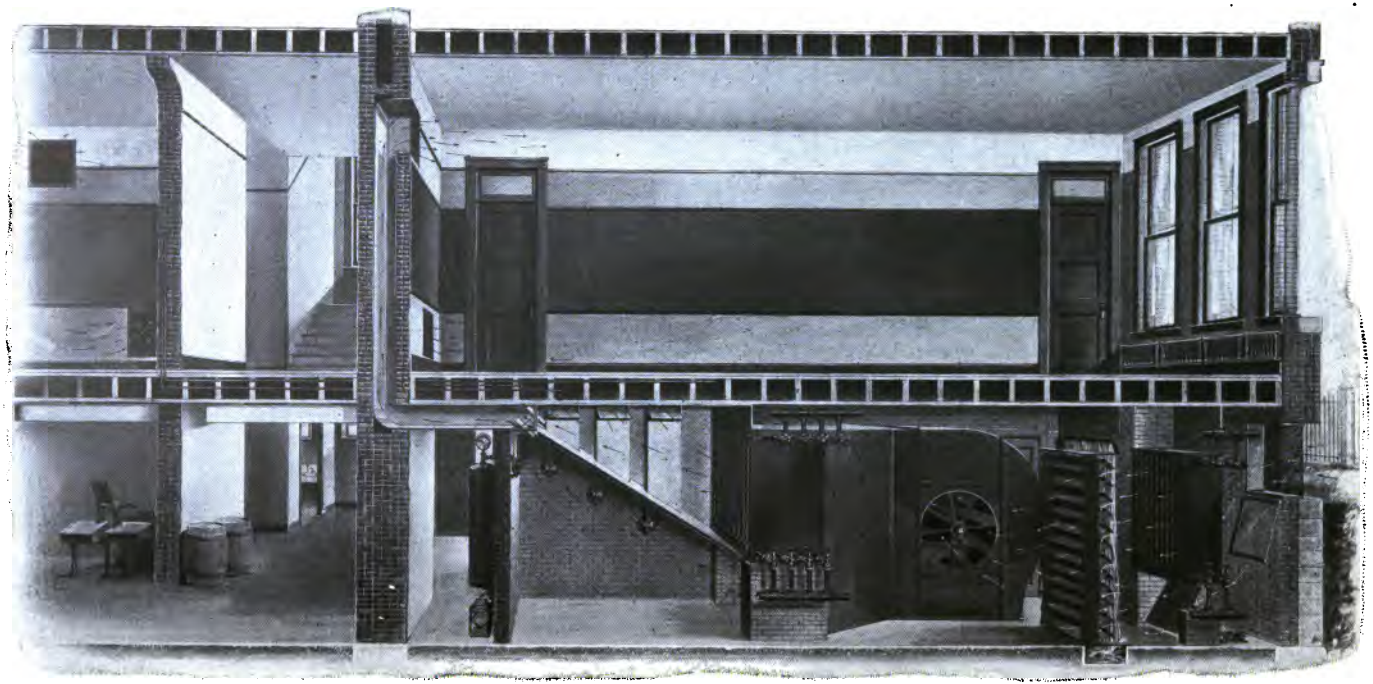
(2) The flue must be so arranged as to insure that all gases are exposed to the highest temperatures, and means of arresting all dust in the flues must be adopted so it cannot escape up the chimney which is about 120 to 180 feet in height.

(3) The main flue must have a large area so that the fumes may travel slowly.

(4) The cost must be reduced to a minimum, and the conditions of labor must be such as can be borne by self-respecting workmen.

With a natural draft, an efficient furnace burns and destroys 600 pounds of garbage per hour on a grate area of 25 square feet, but with forced draft from 10 to 25 tons may be destroyed. The combustible material in the garbage is about 30 per cent and the amount of moisture should not exceed 30 per cent. It should cost about 35 cents per ton to destroy the garbage. Sometimes a boiler is placed above the destructor to generate steam, which is utilized for driving various machines for crushing clinker, disinfecting apparatus, and producing electricity.

Residue. After the garbage is destroyed, a clinker is the result, which is only one-fourth the weight of the original garbage. This clinker consists of 74 per cent slag and other matter insoluble in muriatic acid, and it is used to make concrete, being mixed with Portland cement. It is also used for making roads, for flagging, etc., and is sometimes mixed with lime and water to make mortar.



SECTIONAL VIEW OF BUILDING EQUIPPED WITH VENTO CAST-IRON HOT-BLAST HEATERS
Installation Shows Method of Warming and Ventilating a School Building
Courtesy of American Radiator Company, Chicago

STEAM AND HOT WATER FITTING

STEAM BOILERS AND CONNECTIONS

Small Cast-Iron Boilers. For small low-pressure steam heating jobs, boilers made up of very few sections are used. Two types are illustrated in Figs. 1 and 2. The ratings of such boilers range, as a rule, from about 200 square feet to 800 square feet. These figures and those following are intended to give merely a general idea of the capacities of boilers of various types. There is no hard and fast rule governing the matter, manufacturers varying greatly in their practice. The ratings mentioned are given in the number of square feet of direct radiation the boiler is rated to supply, with steam at from 3 to 5 pounds' pressure when the radiators are surrounded by air at 70° F.

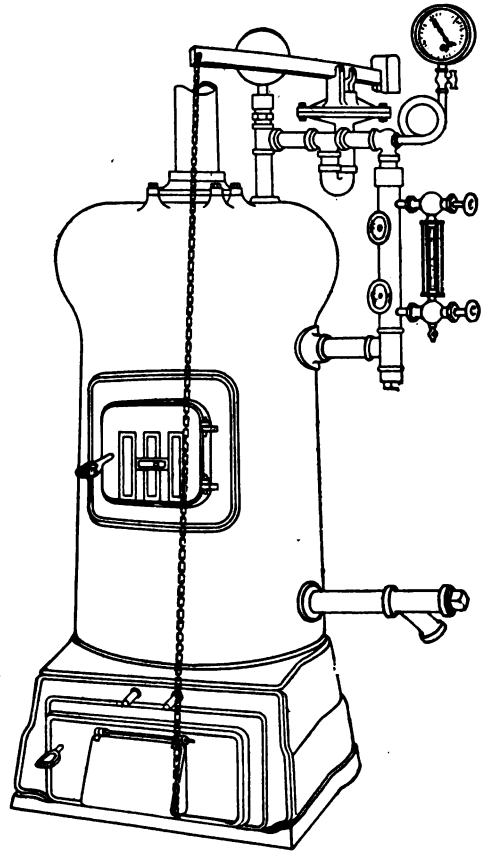


Fig. 1. Small Low-Pressure Steam Heating Boiler.

Boilers similar, in a general way, to the one illustrated in Fig. 3 are used for jobs somewhat larger than the boilers above described would be adapted to. These

boilers have grates ranging generally from 18 inches to 36 inches diameter, and are rated from about 300 square feet to 1,600 square feet, or more.

Cast-Iron Boilers with Vertical Sections. The boilers just described have the disadvantage of not being capable of having their grate surface increased by adding sections, as may readily be done with boilers having vertical sections.

Boilers for jobs having anywhere from 500 to 5,000 square feet of surface, or more, are made

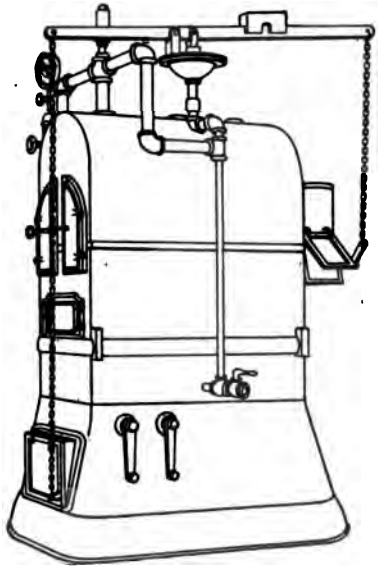


Fig. 2. Small Low-Pressure Steam Heating Boiler

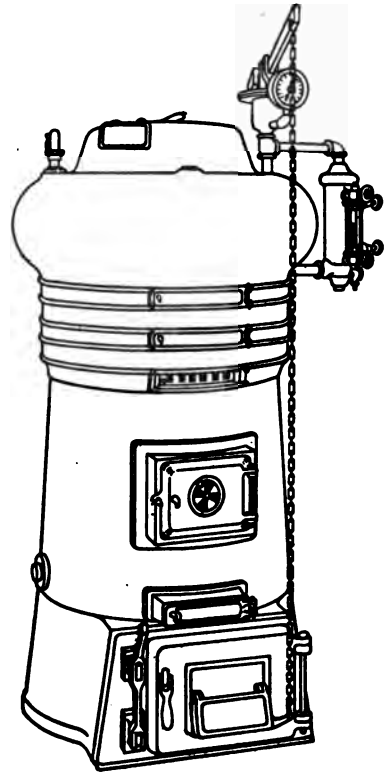


Fig. 3. Steam Heating Boiler

up of vertical sections, as in Fig. 4, connected either by slip nipples or by drums and nipples with long screws and lock-nuts. Very many slip-nipple boilers are now being manufactured owing to ease of erection.

The larger sizes of vertical sectional boilers are often made up of two sets of sections placed opposite each other, as shown in Fig. 5. Such boilers are rated up to 6,000 square feet and over.

The manufacturers of cast-iron boilers have overrated the

capacity of their boilers for an installation in which there is a relatively long time between firings, say 8 or 10 hours, such as in residences. On this account, a well-designed heating system demands, for such cases, the selection of a boiler whose manufacturer's rating is from 40 to 50 per cent in excess of the calculated radiation required.

Arrangement of Grates. Certain makers, in order to avoid making patterns for a boiler with a wide grate, secure the necessary grate surface by adding to the length. For ordinary low-pressure heating, the efficiency of any grate over 6 feet in length falls off very rapidly, owing to the difficulty of properly caring for the fire. Six feet should be considered about the limit for the length of a grate in a low-pressure boiler.

Not long ago few portable boilers with grates wider than 36 inches were manufactured. Now, boilers with 42-inch, 48-inch, and even wider grates, are common.

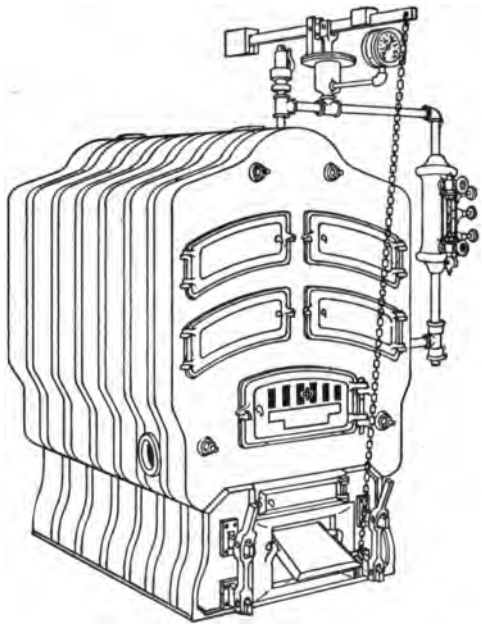


Fig. 4. Steam Heating Boiler with Vertical Sections

Selection of Boilers. It is well in selecting a boiler, to see that the proportion of heating surface to grate surface is not less than 16 to 1, and in large boilers not less than 20 to 1; that the fire-box is deep, so that ample coal may be put on to burn through the night; that the grate is not too long for convenient firing and cleaning; that there is ample steam space; and that the water line is not broken into too many small areas involving the likelihood that water will be lifted by rapid evaporation and wet steam result. See to it, also, that the ash-pit is deep, and that the grate is of a design that will permit convenient operation of the boiler.

On large jobs, it is better, as a rule, to use two boilers. One

must remember that a plant must be designed for the coldest weather; and since the average temperature during the heating season is, in many Northern sections, not far from 40°, one of a pair of boilers will be sufficient under average conditions to do the work with economy; whereas a single, large boiler, during a good part of the heating season, would have to be run with drafts checked and under very unfavorable conditions as to economy. It is almost as poor economy to have too large a boiler as to have one too small.

Boilers for Soft Coal. Some boilers for burning soft coal are arranged with a perforated pipe or duct discharging heated air above the fire to make the combustion more complete and thus diminish the

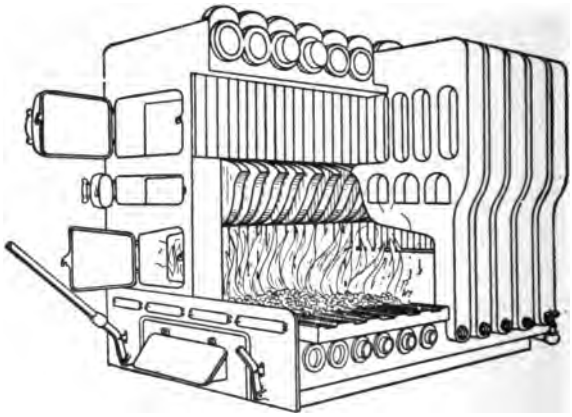


Fig. 5. Vertical Sectional Boiler

amount of smoke given off. This arrangement is of somewhat doubtful utility, since it is difficult to heat the air properly, and to regulate its admission. It is necessary, for soft coal boilers, that the flues and smoke-pipe be larger than for hard coal heaters, in order to provide for the more rapid accumulation of soot.

Down-draft boilers for the use of soft coal are being used very extensively in soft coal districts. In down-draft boilers, the air is drawn down through the fire, which is on a water-cooled grate, instead of passing upward in the usual manner. These boilers are made in the vertical sectional cast-iron type and also in the steel fire-box type of boiler. The fire-box boiler is used generally in larger installations of from 4,000 to 10,000 square feet of radiation.

The down-draft boilers require a more intense draft than the

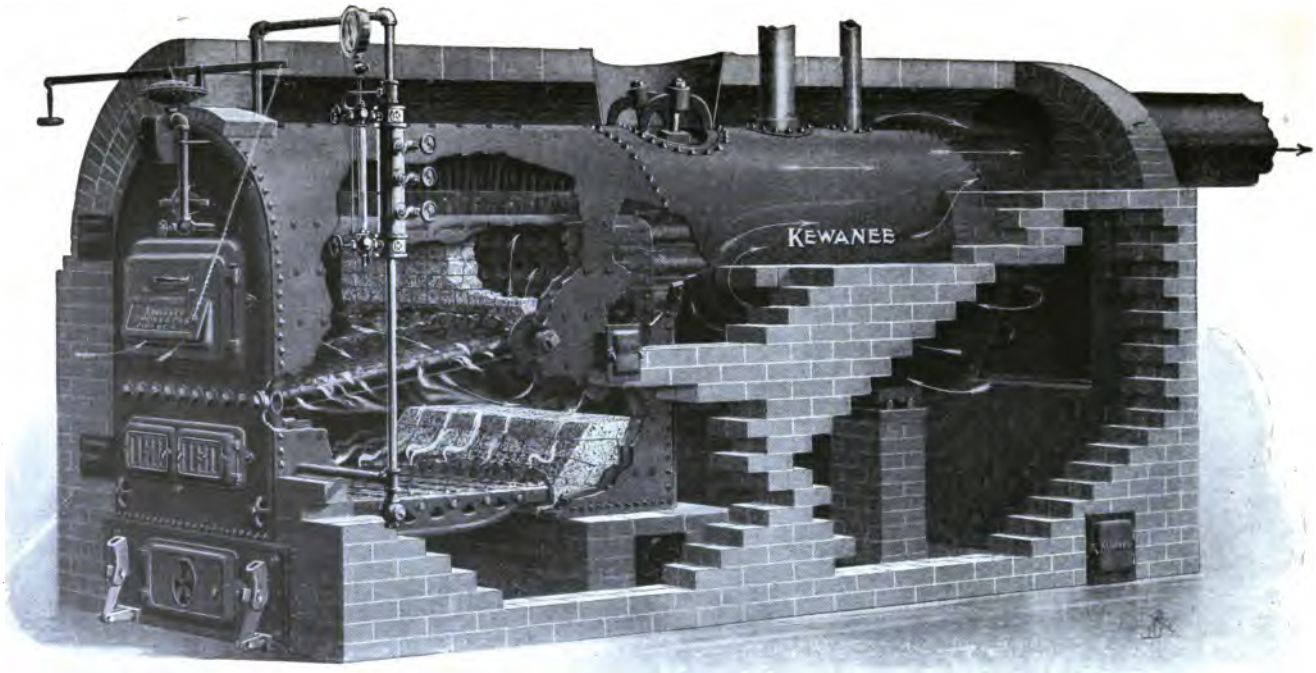


Fig. 3. Sectional View of Smokeless Fire-Box Boiler—Brickset Type, Showing Arrangement of Double Grates
Courtesy of Kewanee Boiler Company, Kewanee, Illinois

ordinary boiler and care should be taken to obtain a stack of good capacity. The manufacturers of these boilers publish in their catalogs the size of stack required. Fig. 6 shows a steel fire-box down-draft boiler.

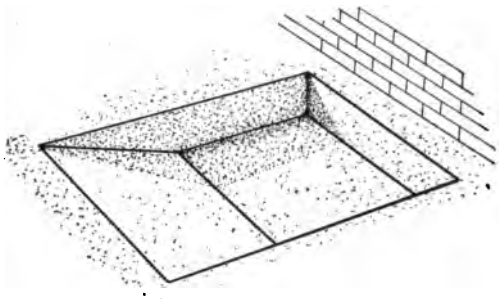


Fig. 7. Pit for Collection of Hot Ashes

Coke Boilers. Coke is a popular fuel in some parts of the country; and certain makers are putting out specially designed boilers for this service, having a very deep fire-box.

Ash Pits. The ash-pits under most boilers are rather shallow; therefore it is a good plan to excavate and build a pit not less than 4 to 6 inches below the floor, to give additional space for the collection of hot ashes, thus avoiding the burning-out of grates. Such pits should be built preferably of concrete as shown in Fig. 7.

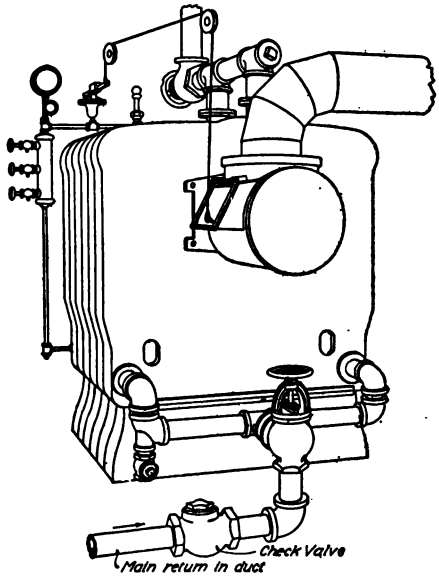


Fig. 8. Typical Arrangement of Return, Showing Check Valve

Boiler Connections. Small jobs frequently have no stop valves at the boiler. In the case of larger ones, or where there are two boilers, valves in the supply mains must always be accompanied with check valves in the returns; otherwise, in case a stop valve in the main steam line is closed, the water will be backed out of the main returns at the boiler, by the pressure. Should the water partially leave the boiler in this manner and then suddenly return, the water coming in contact with the heated sections will crack them.

A stop valve should be placed between the boiler and the check valve in the return. A typical arrangement of return, etc., is shown

in Fig. 8. It is convenient to have an independent drain connection from the returns to provide for drawing off the water in the system without emptying the water from the boiler. The latter, of course, has its independent blow-off cock. The water supply to the boiler should be controlled by a lock-shield valve or a cock that cannot be tampered with by any person not in charge. Boilers having eight sections or more, as a rule, have two or more steam outlets, thus reducing the likelihood of the boiler priming or making wet steam, since, with a single outlet, the velocity of steam through it may be so great that the water is picked up and carried into the piping system.

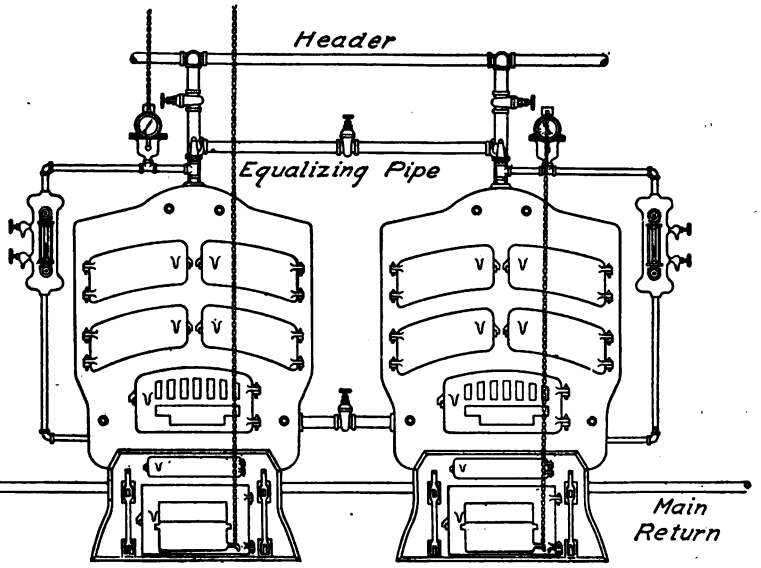


Fig. 9. Method of Connecting Two Boilers.

When two boilers are to be connected, especial care must be taken to make them maintain an even water line when working together. Fig. 9 shows a method of making these connections that is simple and effective. The valved connection between the two boilers, below the water, gives free communication between them, making them work as one and preventing a difference in the water level in the two boilers. The equalizing pipe is often omitted, the header being made about twice the diameter of the pipes leading to it from the boilers.

The returns are connected with the twin boilers practically as

shown in Fig. 8, the check valve being placed between the stop valve of each boiler and the main return.

Boiler Fittings or Trimmings. It is important to have a reliable safety-valve, preferably one of the "pop" type specially designed for steam heating systems.

The damper regulators used are of the ordinary diaphragm pattern, and should be connected by chains with both the lower draft door below the grate, and with the cold-air check in the smoke connection.

The steam gauge with siphon, the water column, water gauge, gauge cocks, etc., require no special description.

Capacity of Boilers. Boiler capacities are commonly expressed in the number of square feet of direct radiating surface they will supply without undue forcing. Mains and risers should, of course, be added to the actual amount of surface in the radiators and coils. Even if the pipes are covered, a small allowance should be added to the combined surface of the radiators. Not less than 50 per cent, and preferably 60 per cent, must be added to indirect radiation, to reduce it to equivalent direct radiation; and not less than 25 to 30 per cent to direct-indirect radiation, to get its equivalent in direct surface. Another point to be kept in mind in selecting a boiler for heating rooms to be kept at different temperatures, is that more heat is given off per square foot of radiation in a room at 50°, for example, than in a room kept at 70°, the amount given off being approximately proportional to the difference in temperature between the steam and the air. With steam at, say, 220°, corresponding to a trifle over 2 pounds' pressure, the difference, in the case assumed, would be $220° - 50° = 170°$, and $220° - 70° = 150°$. That is, the actual amount of radiation in the rooms to be kept at 50° should be multiplied by $\frac{170}{150}$ to ascertain the amount of radiation in a 70° room that would give off the same amount of heat.

It is common practice to allow roughly for the loss of heat from uncovered mains, branches, and risers, by adding about 25 per cent to the actual direct radiating surface in radiators and coils.

Example. What should be the capacity of a boiler to supply steam to 1,000 square feet of direct radiation in a room to be kept at 70°, to 800 square feet of indirect radiation; and to 1,500 square feet of direct radiation, in rooms to be kept at 50° F.?

Direct radiation	1,000 sq. ft.
Equivalent in direct radiation of 800 sq. ft. of indirect = 800 × 1½ =	1,200 " "
Equivalent in direct radiation, in rooms at 70°, of 1,500 sq. ft. in rooms at 50° = ⅞ × 1,500 =	1,700 " "
Total equivalent D. R. S. (direct radiating surface) exposed in 70° air =	3,900 sq. ft.
Add 25 per cent of actual surface to allow approximately for piping =	825 " "
Total equivalent D. R. S., or Boiler Rating =	4,725 sq. ft.

Grate Surface and Heating Capacity. It is advisable always to check the catalogue ratings of boilers as follows, when selecting one for a given service:

Suppose the Direct Radiating Surface, including piping, is 3,000 square feet. One square foot, it may be assumed, will give off about 250 heat units in one hour—a *heat unit* being the amount of heat necessary to raise the temperature of 1 pound of water 1 degree Fahrenheit. A pound of coal may safely be counted on to give off to the water in the boiler 8,000 heat units. Now, 3,000 sq. ft. × 250 heat units ÷ 8,000 heat units, gives the amount of coal burned per hour; and this, divided by the square feet of grate, gives the rate of combustion per square foot per hour. Suppose in this case, the grate has an area of 15 sq. ft.; then $\frac{3000 \times 250}{8000 \times 15} = 6.25$ pounds coal burned per square foot of grate surface per hour. This is not a high rate for boilers of this size, though for ordinary house-heating boilers the rate should not exceed 5 pounds; and for small heaters having 2 to 4 square feet of grate, the rate should be as low as 3 to 4 pounds per square foot of grate per hour. Otherwise, more frequent attention will be required than it is convenient to give to the operation of such small boilers. This is where depth of fire-box plays an important part, for, with a shallow fire, the coal quickly burns through, necessitating frequent firing.

Coal Consumption. For house-heating boilers a fair maximum rate of combustion is 5 pounds per square foot of grate per hour. In many residences it is the custom to bank the fire at night, when the rate will fall to, say, 1 pound. In cold weather, then, one square foot of grate would burn 5 pounds of coal for each of 16 hours, and 1 pound during each of the remaining 8 hours, a total of 80 + 8 = 88 pounds.

In many sections of the country, the average outside temperature during the heating season is about 40°; and since the heat required is proportional to the difference in temperature between indoors and outside, the average coal consumption would be only $\frac{70° - 40°}{70° - 0°} = \frac{3}{7}$ of the maximum in zero weather.

With a heating season of 200 days, the coal burned on one square foot of grate would be $200 \times \frac{3}{7} \times 88 = 7{,}600$ pounds in round numbers, corresponding to an average rate throughout the season of $\frac{7{,}600 \text{ pounds}}{200 \text{ days} \times 24 \text{ hrs.}} = 1.6$ pounds approximately.

A method of approximating the coal consumption for a given amount of radiating surface, designed to maintain a constant temperature in rooms of 70° day and night, would be to multiply the surface (which, for example, take at 1,000 square feet, including allowance for mains) by 250 heat units—the amount given off by a square foot per hour—and then multiply the product by $\frac{3}{7}$, as explained above, to allow for average conditions. This gives $1{,}000 \times 250 \times \frac{3}{7}$, which, divided by 8,000 heat units per pound of coal, gives the weight of coal required per hour; and this, multiplied by the hours per season, gives the total consumption.

Non-Conducting Coverings. It is customary to cover cast-iron sectional boilers with non-conducting material composed as a rule chiefly of asbestos or magnesia applied in a coating $1\frac{1}{2}$ to 2 inches thick, the exterior being finished hard and smooth.

Exposed basement piping in first-class work is covered with sectional covering $\frac{3}{4}$ inch to 1 inch thick, according to the character of the work.

The loss of heat through fairly good coverings, is not far from 20 per cent of the loss from a bare pipe, which, with low-pressure steam, is approximately 2 heat units per square foot per hour for each degree difference in temperature between the steam and the surrounding air.

STEAM RADIATORS AND COILS

Direct Radiators. The commonest forms of radiators to-day are the cast iron vertical loop varieties, types of which are shown in Figs. 2 and 13 in Part I (Heating and Ventilation). These are

made up with slip-nipple or screw-nipple connections, the standard height being about 36 to 38 inches.

It is, of course, advisable to use radiators of standard height when possible, since they are cheaper than the lower radiators, which must

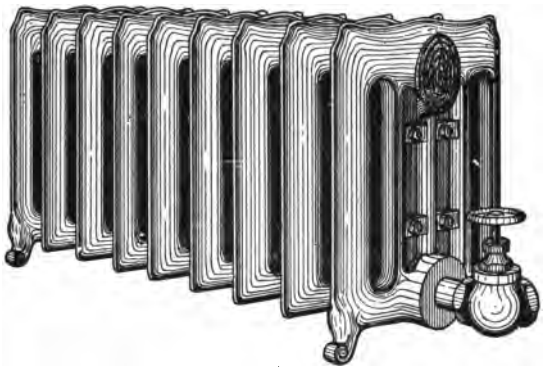


Fig. 10. Low Radiator to be Placed Below Window Sill.

be used when placed below window sills (see Fig. 10). Single-column radiators are more effective than those having a greater number of vertical loops, since in the latter the air flow is retarded and the outer loops cut off the radiant heat from the inner ones. Radiators with four or more columns are generally used where the length of the space in which they must be placed is limited.

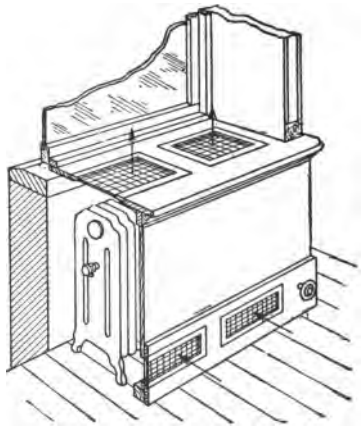


Fig. 11. Concealed Radiator with Register Face.

Wall radiators (see Fig. 4, Part I, Heating and Ventilation) have become very popular because of their neat appearance and the small distance they project into the room. They are very effective heaters, and, although more expensive than certain other types of cast-iron radiators, less surface is required, which tends to offset the increased cost. These radiators are made up in such a variety of forms that they can be adapted to almost any location.

Concealed Radiators. A favorite method of concealing radiators

is to place them below window-sills, with a grating or register face in front of and above them, as shown in Fig. 11. By this arrangement, the radiant heat is to a great extent cut off. The gratings must have ample area to permit the free circulation of air, and should have not

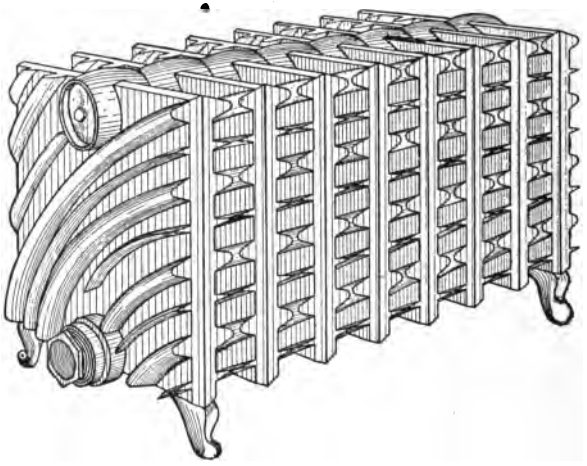


Fig. 12. Radiator for Use without Gratings.

less than 2 or $2\frac{1}{2}$ square inches of free area to each square foot of radiating surface, for inlets and outlets respectively. It is advisable to increase these allowances when possible.

The same rule applies to radiators placed below seats. A radia-

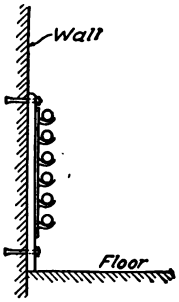


Fig. 13. Hook Plates.

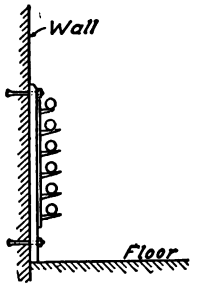


Fig. 14. Expansion Plates.

tor designed specially for this purpose, for use without gratings, is shown in Fig. 12.

Wall Coils. An ordinary wall coil or manifold coil, made up generally of $1\frac{1}{4}$-inch pipe, with branch tees or manifolds, is illustrated

in Fig. 39, Part I (Heating and Ventilation). The long runs of such coils rest on hook plates (Fig. 13); the short pipes near the corner, on expansion plates (Fig. 14), on which the pipes are free to move when the long pipes expand. Such coils are very effective when placed below the windows of a factory, in which class of buildings they find their widest application.

Miter Coils. Miter coils, as shown in Fig. 15, are used for overhead heating, the coils being suspended about 8 to 10 feet from the floor, and 3 to 4 feet from the walls. A good type of hanger is shown in Fig. 16. The same type of coil, when placed alongside a wall, is known in certain sections as a *harp* coil (see Fig. 17), and may be used where long runs must be made along a wall, but where it is impossible to install the type of coil shown in Fig. 39, Part I (Heating and Ventilation), owing to doorways or other obstructions. Two harp coils could be used along a wall, for example, avoiding a doorway; and the expansion of the pipes would be provided for by the short vertical lines.

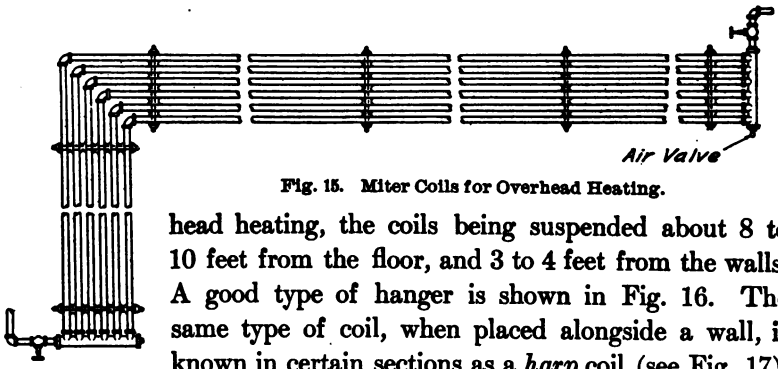


Fig. 15. Miter Coils for Overhead Heating.

Return-Bend Coils. Return-bend coils, known in some parts of the country as *trombone* coils, are shown in Fig. 40, Part I (Heating and Ventilation). These are suitable only for rather short runs, since the steam must pass through the several horizontal pipes successively, and, if the radiating surface is greater than the capacity of the upper line of pipe to supply it properly, the steam is condensed before reaching the lower lines. With the harp or other coils having headers or branch tees, sufficient steam can enter to fill all the pipes at once, passing through the parallel lines at the same time.

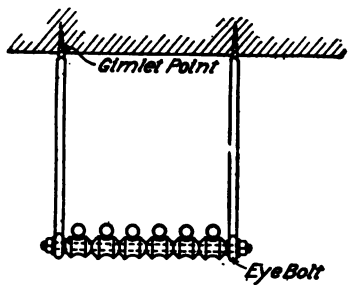


Fig. 16. An Approved Type of Hanger.

Direct-Indirect Radiators. A *direct-indirect* radiator is shown in Fig. 18. The air enters through a louvered or slatted wall opening with screen. Provision is made to shut this off and admit air simultaneously from the room, making the radiator essentially a direct radiator when the cold air is shut off. The best location for the cold-air opening is probably just below the sills, the wall boxes being less conspicuous in this position.

Two forms of indirect radiators are

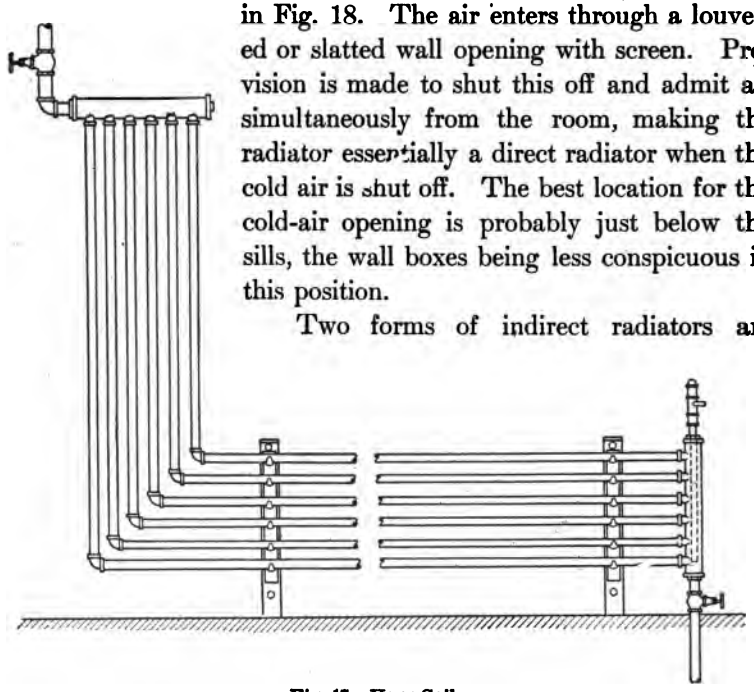


Fig. 17. Harp Coil.

shown in Fig. 7, Part I, and Fig. 3, Part II (Heating and Ventilation), the shallow sections being used largely for house heating, the deep ones for schoolhouse systems. The latter are provided with extra long nipples for spacing the sections about 4 inches on centers, to give a proper passage for a large volume of air.

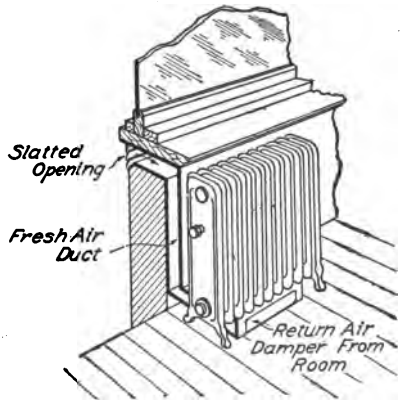


Fig. 18. Direct-Indirect Radiator.

Indirect Radiators. The indirect radiators are enclosed in galvanized-iron casings about 30 inches deep, giving a space of 6 or 8 inches above and below the radiators. The beams over the radiators are commonly covered with rough boards, to which tin or

tin and asbestos is nailed, the casing being flanged at the top and screwed or nailed to these boards.

The casings should be made with corners of a type that will permit the ready removal of the sides in case of repairs being needed; and the bottom of the casing should be provided with a slide for inspection and cleaning. The larger sections, when used for schoolhouse heating, are arranged as shown in Fig. 19, with a mixing damper designed to cause a mingling of the warm and cold air in the flue, the volume discharged being but slightly reduced, with a decrease in temperature due to opening the damper to cold air. The space for the passage of air between the shallow sections containing about 10 square feet each, is about $\frac{1}{3}$ of a foot; the space between the sections of the deep pattern is not far from $\frac{1}{2}$ a foot when the sections are properly spaced.

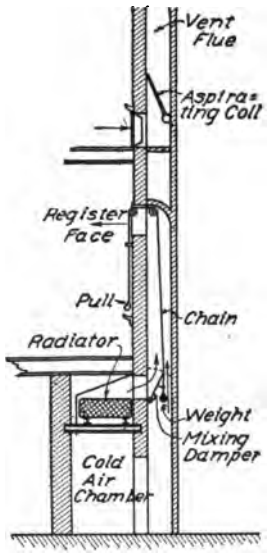


Fig. 19. Arrangement of Casings for Use in Connection with Indirect Radiators.

Heat Given Off by Steam Radiators. Of the heat emitted by direct radiators, approximately one-half is by radiation, the balance by convection or the contact of air. Since practically no heat is radiated from concealed radiators, it is very important that proper provision should be made for the passage of an adequate volume of air over the heating surface.

TABLE I

Heat Units Emitted from Radiators and Coils

Radiation per square foot of radiating surface per hour.—In rooms at 70° F. temperature.—With steam at 3 to 5 pounds' pressure.

Type of Radiator	Heat Units Emitted (Approximate)
Concealed cast-iron direct radiators	175–200
Ordinary cast-iron vertical-section radiators	250
Wall radiators	300
Pipe coils on walls	325
Pipe coils overhead (pipes side by side)	350
Ordinary cast-iron extended-surface indirect radiators (air admitted from outdoors)	400

Wall radiators and coils give off more heat under the same conditions than is emitted by ordinary vertical cast-iron radiators.

Much might be said regarding the efficiency of radiators due to their height, form, and arrangement. For the purposes of this course, however, only fair average values will be given, as set forth in Table I, a discussion of radiator tests, etc., being omitted to avoid unnecessary detail.

STEAM PIPING

Size of Main for Circuit System. Since the main of a circuit system, as described in Part I (Heating and Ventilation), must carry both steam and water of condensation, it should be made considerably larger in proportion to the surface supplied than mains which are dripped at intervals or which carry only the condensation from the main itself.

Sizes, ample for circuit mains of ordinary length, are indicated in the accompanying table:

TABLE II

Sizes of Circuit Mains

Diameter of Circuit Main	Direct Radiating Surface
2 inches	200 sq. ft.
2½ "	350 " "
3 "	600 " "
3½ "	900 " "
4 "	1,200 " "
4½ "	1,700 " "
5 "	2,100 " "
6 "	3,000 " "

Dry Return System. In many cases it is desirable to run the supply and return mains overhead. Such systems contain less water than wet return systems, and are therefore more susceptible to changes in the fire, because of the smaller quantity of water in the apparatus. The return mains must be made larger than when they are placed below the water line, since they are filled with steam, except the space occupied by the return water running along the bottom. The pipes should have a greater pitch than wet returns.

With dry returns, if certain supply risers are of inadequate size, steam is apt to back up into the radiator through the dry returns and to cause a holding-back of the water in the radiators. To prevent this,

check valves are sometimes introduced in the branch returns. If the piping is properly proportioned, however, this is unnecessary. Siphon drips are frequently used, as explained in Part I (Heating and Ventilation).

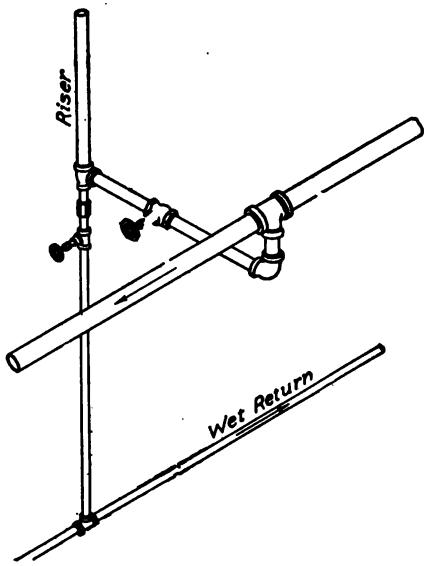


Fig. 20. Wet Return System.

Wet Return Systems. This system, illustrated in Fig. 20, provides for water sealing all returns and drips, and avoids the backing-up action mentioned above. Suppose, for example, the pressure in one of the vertical returns is ½ pound less than in the others; then, since a column of water 2.3 feet high corresponds to 1 pound pressure, the water will back up this particular return about 1.15 feet higher than in the others and thus equalize the difference in pressure. Where the mains must be long, the wet return system affords the opportunity to rise and drip the supply main as often as necessary; whereas, with the dry return system, the main and return have a gradual pitch from start to finish. This often brings the return so low as to interfere with head room. With the wet return system the return may be dropped below the floor line at doorways without interfering with the circulation. The sizes of wet returns may be made considerably smaller than dry returns for a given radiating surface, as shown in Table III.

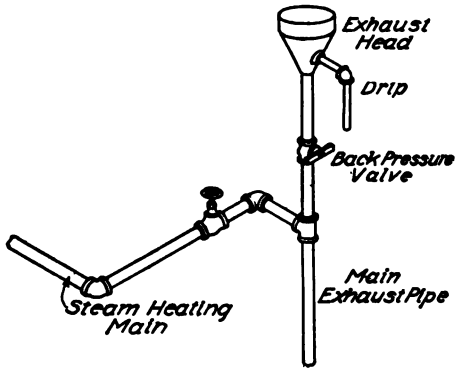


Fig. 21. Overhead Feed System.

Overhead Feed System. The overhead feed system (see Fig. 21)

is most commonly used in connection with exhaust steam plants, since in such systems the exhaust pipe from the engines must be carried to the roof, and the steam supply to the building may conveniently be taken from a tee near the upper end of this pipe. The main should be pitched down, and outlets taken from the bottom, to drain the condensation through the risers (see Fig. 22). With this system the water of condensation always flows in the same direction as the steam; hence the horizontal pipes and the risers may be made somewhat smaller than in up-feed systems.

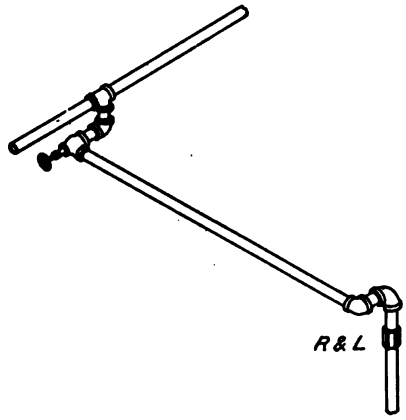


Fig. 22. Outlet Taken from Bottom of Main.

This system has the advantage of placing the big pipes in the attic, where their heating effect is less objectionable than in the basement. As the pipes gradually decrease in size from top to bottom, this gives small pipes on the lower floors, which in modern buildings generally contain a few large rooms and little space for concealing pipes. It is frequently advisable to combine with this system the up-feed method of heating the first floor, which is generally high-studded and requires a large amount of radiation. Relieving the down-feed system of this load means smaller risers throughout the building, which, in the modern sky-scraper, results in a saving that more than offsets the cost of the separate up-feed system for the lower floor. Another reason why it is advisable to put the lower floor on a separate system, is that the steam is dry, whereas the steam from an overhead system becomes pretty wet from condensation by the time it reaches the lower floor.

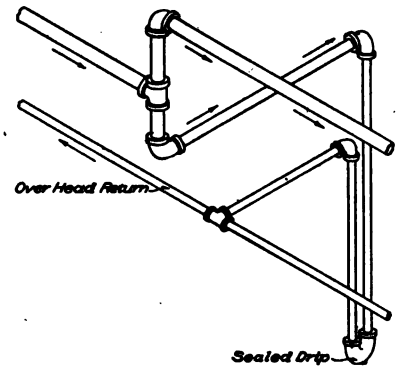


Fig. 23. Siphon Trap.

One-Pipe System. The one-pipe up-feed system is most commonly used in connection with relatively small heating plants. It has the advantage of simplicity, there being but a single valve to operate. In tall buildings with the up-feed system, the risers must be objectionably large to provide for the passage of steam up, and water of condensation down, the same pipe. With the overhead system, the risers may be made considerably smaller, since the water is not hindered in its passage by a flow of steam in the opposite direction. With this one-pipe system, the radiator connections should be short and pitched downward toward the risers to avoid pockets. When used in high buildings with the overhead system, the lower portion of the risers must be liberally proportioned, otherwise the steam will become too wet.

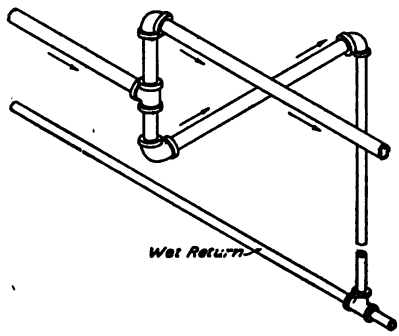


Fig 24. Arrangement to Rise and Drip in Mains at Intervals.

The Two-Pipe System. This system is commonly used where the radiator connections must be long and where it would be impossible to secure a proper pitch to insure good drainage with one-pipe radiator connections. Coils are nearly always made up with two-pipe connections. In high buildings, where a large amount of radiation must be carried by each riser, they may be made smaller if two-pipe connections are made with the radiators. This is often a decided advantage, especially if the risers are to be concealed.

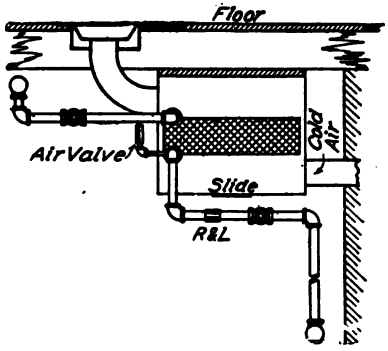


Fig. 25. Arrangement for Draining with Indirect System.

Draining Mains and Risers. With long mains, it frequently is the case that if given a continuous pitch they would be too low at the extreme ends; and it is therefore customary to rise and drip at intervals, as shown in Figs. 23 and 24.

The *siphon trap* (Fig. 23) prevents a greater pressure being introduced along the overhead return than occurs at the extreme end, since any excess in pressure at an intermediate point merely forces down the water in the inlet leg of the siphon trap to a point where the difference in pressure in the two mains is equalized by the higher level of water maintained in the outlet pipe of the syphon trap.

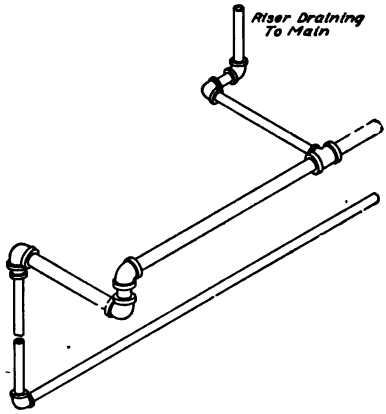


Fig. 26. Risers Drained to Main and Main Drained at End.

With indirect systems, the mains are frequently drained through the benches or stacks of radiators, the connections being taken from the bottom of the main. It is assumed that all the indirects will not be shut off at the same time (see Fig. 25).

Mains and risers are commonly drained as shown in Fig. 20, connections being taken from the bottom of the main and the heel of the riser. Risers are not infrequently drained to the main, which in turn is drained at the end (see Fig. 26). This arrangement requires less fitting than when the

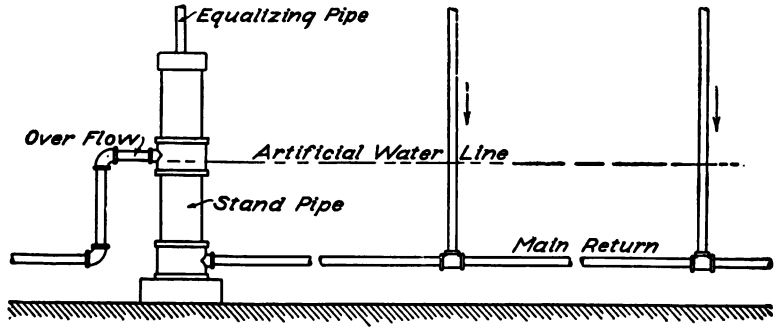


Fig. 27. Showing Artificial Water Line.

risers are relieved at the base, as shown in Fig. 20. If the mains are long, they should be dripped at intervals of 50 to 75 feet.

Overhead-feed mains on a down-feed system are nearly always dripped from the bottom to the various risers, as previously stated.

Artificial Water Line. It is sometimes necessary, when a boiler

is set very low with reference to the returns, and it is desired to use a wet return system, to seal the relief pipes by means of an artificial water line established as shown in Fig. 27. The equalizing pipe is to be connected with a steam main.

When the discharge from the system leads to an open return, a trap must be used. One of the type shown in Fig. 28, arranged with an equalizing pipe and set at the proper level, will hold the water line in the system, no standpipe being required.

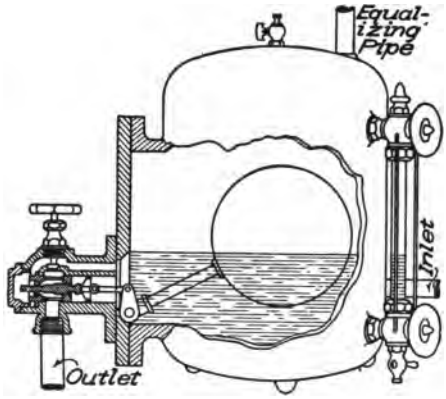


Fig. 28. Water Line Trap with Equalizing Pipe.

Pipe Sizes.—Mains. The capacities of pipes to supply heating surface increase more rapidly than their sectional areas; that is, a 6-inch pipe, with about four times the area of a 3-inch pipe, will supply nearly six times as much surface.

Table III shows the amounts of radiating surface in gravity-return systems which main pipes 100 feet long, of different diameters, may be safely counted on to supply with low-pressure steam (say, 3 to 5 lbs.).

In case the radiating surface is located some distance above the water line in the boiler, the carrying capacity of the pipes may be increased as much as 50 per cent, owing to the greater drop in pressure that may be allowed without interfering with the return of water to the boiler.

Mains are frequently made much larger than necessary, simply because the fact has been overlooked that the radiators are located well above the boiler, and that a drop in pressure between the boiler and the end of the main of $\frac{1}{4}$ lb., or even more, would be permissible.

The greater the drop in pressure allowed the smaller may be the pipe for a given capacity.

Pipe Sizes.—One-Pipe Risers. Riser capacities are given in Table IV.

TABLE III

Capacity of Supply Mains, Gravity Return System, and Size of Dry and Wet Returns

Mains 100 ft. long.—Steam at low pressure (3 to 5 lbs.).

Diameter of Supply Pipe	Capacity in Direct Radiating Surface	Diameter of Dry Return	Diameter of Wet Return
1 inch	55 sq. ft.	¾ inch	¾ inch
1¼ inches	115 " "	1 "	1 "
1½ "	175 " "	1¼ inches	1¼ inches
2 "	325 " "	1½ "	1¼ "
2½ "	570 " "	2 "	1½ "
3 "	1,000 " "	2½ "	2 "
3½ "	1,480 " "	3 "	2½ "
4 "	2,000 " "	3 "	2½ "
4½ "	2,770 " "	3 "	2½ "
5 "	3,500 " "	3½-4 "	3 "
6 "	5,700 " "	4-5 "	3½-4 "
7 "	8,800 " "	4-5 "	4 "
8 "	12,000 " "	4-5 "	4 "
10 "	20,000 " "	5-6 "	4 "
12 "	33,000 " "	5-6 "	4-5 "

For lengths greater than 100 ft. and for same drop in pressure as for 100 ft., multiply the above figures by 0.8 for 150 ft.; 0.7 for 200 ft.; 0.6 for 300 ft.; 0.5 for 400 ft.; 0.4 for 600 ft.; and 0.3 for 1,000 ft. When the pressure at the supply end of the pipe can be increased for long runs so that the drop in pressure for each 100 ft. can be the same, then the figures in the table can be used for long runs.

TABLE IV

Capacities of One-Pipe Risers

Size of Pipe	Capacity, Up-Feed	Capacity, Down-Feed
1 inch	30 sq. ft.	60 sq. ft.
1¼ inches	60 " "	110 " "
1½ "	120 " "	160 " "
2 "	200 " "	260 " "
2½ "	300 " "	400 " "
3 "	450 " "	600 " "
3½ "	620 " "	800 " "
4 "	800 " "	1,000 " "

The capacities of the 1-inch and 1¼-inch pipes for up-feed are somewhat greater than those stated; but they are given as above, since these figures correspond closely to standard radiator tapping, and it is advisable to make the pipes of the same size as the tapped openings.

In high buildings with the down-feed system, the lower half of the risers should be based on not much more than half the capacities stated in the right-hand column, in order that the pipes may be of ample size to carry off the great amount of condensation from the radiators above, without making the steam too wet for use in the radiators below. The pipe to the lowest radiator connection should be not less than 2-inch.

Pipe Sizes.—Two-Pipe Risers. With the two-pipe system, the capacity of the risers is of course, considerably greater than with the one-pipe system, since the condensation is carried off through a separate system of returns.

Table V gives the approximate capacities of risers for the two-pipe system.

TABLE V

Capacities of Two-Pipe Risers

Size, Supply Riser	Capacity, Up-Feed System	Capacity, Down-Feed System	Size, Return Riser
1 inch	50 sq. ft.	55 sq. ft.	¾ inch
1¼ inches	100 " "	115 " "	1 "
1½ "	150 " "	175 " "	1 -1¼ inches
2 "	270 " "	325 " "	1 -1¼ "
2½ "	470 " "	570 " "	1¼-1½ "
3 "	840 " "	1,000 " "	1¼-1½ "
3½ "	1,200 " "	1,480 " "	1½-2 "
4 "	1,600 " "	2,000 " "	1½-2 "

In buildings over six stories high, with the up-feed system, use 10 per cent less surface than stated in the third column, to allow for the increased length and condensation.

Pipe Sizes, Indirect. Supply connections with indirect radiators must be larger for a given surface than for direct radiators. The following table gives ample sizes when the radiators are but little above the water line of the boiler. When this distance is considerable, the pipes may be safely rated to supply one-third more surface; for a greater drop in pressure may be allowed between the

TABLE VI

Sizes of Supply Connections for Indirect Radiators

Diameter of Pipe	Indirect Radiating Surface Supplied
1 inch	40 sq. ft.
1¼ inches	70 " "
1½ "	100 " "
2 "	180 " "
2½ "	330 " "
3 "	600 " "
3½ "	900 " "
4 "	1,200 " "
4½ "	1,600 " "
5 "	2,100 " "
6 "	3,400 " "
7 "	5,400 " "
8 "	7,200 " "

supply and the return mains, and drop in pressure means a greater velocity in the pipes, and consequently a greater flow of steam to the radiators.

Indirect radiators are seldom tapped larger than 2 inches; therefore radiators that require larger connections should be subdivided in groups.

STEAM PRESSURES AND TEMPERATURES

Steam pressures and temperatures have a certain definite relation to each other, the temperature increasing with the pressure, but not as rapidly for a given increase with high-pressure as with low-pressure steam. For example, with an increase in pressure from 10 pounds to 20 pounds, the temperature rises about 19° F.; whereas with an increase of 10 pounds from 90 to 100 pounds the temperature increases

TABLE VII

Temperature of Steam at Various Pressures

Vacuum (in Inches of Mercury)	Temp. °F.	Gauge Pressure (lbs. per sq. in.)	Temp. °F.
0	212.1	0	212
5	203.1	1.3	216.3
10	192.4	2.3	219.4
12	187.5	3.3	222.4
14	182.1	4.3	225.2
16	176.0	5.3	227.9
18	169.4	10.3	240.0
20	161.5	20.3	259.2
22	152.3	30.3	274.3
24	147.9	40.3	286.9
26	125.6	50.3	297.8
28	101.4	60.3	307.4
		70.3	316.0
		80.3	323.9
		90.3	331.1
		100.3	337.8
		150.3	365.7
		200.3	387.7

only about 7° F. From atmospheric pressure to 10 pounds' gauge pressure, the increase in temperature is nearly 28° F; a slight difference in the pressure in radiators making a marked difference in their temperature.

In the case of a *partial vacuum*, so called—expressed generally

in inches of mercury—the decrease in temperature as a condition of perfect vacuum is approached is very marked, as shown in table VII, which gives also steam temperatures corresponding to various pressures. The latter are given in each case $\frac{3}{10}$ of a pound in excess of the gauge pressure, as practically all tables of the properties of steam give the absolute pressure—that is, the pressure above a vacuum—the absolute pressure corresponding to 5.3 pounds' gauge pressure, for example, being 20 pounds absolute.

The atmospheric pressure at sea-level is practically 14.7 pounds absolute, and the boiling point of water is 212°. As the pressure decreases, due to altitude or to the removal of air from a vessel by artificial means, the boiling point falls.

EXPANSION

Amount of Expansion. An allowance of $\frac{8}{1000}$ of an inch per 100 feet of pipe for each degree rise in temperature, is a fair allowance in computing the amount of expansion that will take place in a line of pipe.

One must assume the temperature at which the pipe will be put up—say anywhere from 0° to 40° in an unfinished building in winter—and, knowing the pressure to be carried, look up in a table of the properties of saturated steam the temperature corresponding. See table VII.

Example. Find the expansion that will take place in a line 100 feet long put up in 30-degree weather, when it is filled with steam at 80 pounds' pressure. The temperature corresponding to 80 pounds'

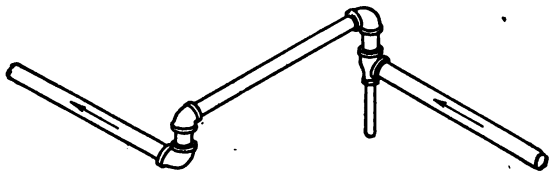


Fig. 29. Offset and Swivels.

steam pressure is 324°; the increase from 30° is 294°, which multiplied by $\frac{8}{1000}$ gives $2\frac{35}{100}$ inches expansion, or, expressed in decimals, 2.35 inches.

In low-pressure work 100 feet of pipe heated from 30° to 230° will expand about 1.6 inches.

Provision for Expansion. The expansion of mains can generally be provided for by offsets and swivels, as shown in Fig. 29. All that is necessary is to have the two vertical nipples placed far enough apart, as determined by the length of the horizontal offset, to permit the expansion to take place without too much turning on the threads. The less the turn, the less will be the likelihood of leakage. The shorter the offsets, the greater the number that must be used.

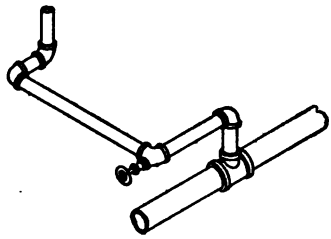


Fig. 30. Swing to Allow for Expansion of Risers.

A pretty conservative rule would be to allow 4 feet of offset to each inch of expansion to be taken up on the line. In the case of underground work a good deal of the expansion can be taken up where pipes enter buildings by the same kind of swings as shown in Fig. 29, making them longer and thus reducing the number of expansion joints or offsets in the tunnel or duct.

Expansion of Risers. In providing for the expansion of risers, considerable skill must be used, especially in tall buildings. In buildings of not over 6 to 8 stories, or possibly 10 floors at the outside, if they are not high-studded, the expansion may all be taken up in the basement, using swings like those shown in Fig. 30, similar swings being used in the attic also if the overhead-feed system is used, the connections being taken from the bottom of the main, as previously stated.

In higher buildings than those mentioned, either slip-pattern expansion joints or swivels made up of pipe and fittings are commonly used. One of these to every six to eight floors is generally considered sufficient, depending on the length and arrangement of the radiator connections. One must be sure the pipes above and below slip joints are in proper alignment; otherwise, binding and leakage will occur. If the risers are concealed, such joints must be made accessible through proper openings in the walls, as the packing will have to be taken up from time to time and replaced.

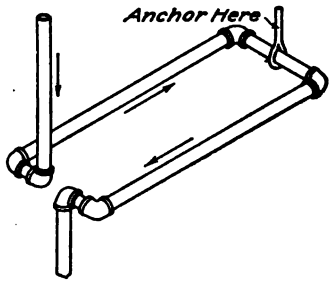


Fig. 31. Expansion Joints. Offsets Nearly Horizontal.

Expansion joints made up of pipes are illustrated in Fig. 31. Such joints are unsightly if exposed; but they may generally be concealed either in specially provided pockets in the floor or in spaces furred down below the ceilings and near the walls.

When expansion joints are used, the risers should be anchored about midway between them. These anchors consist merely of clamps around the pipes fastened to the beams, one type being shown in Fig. 32.

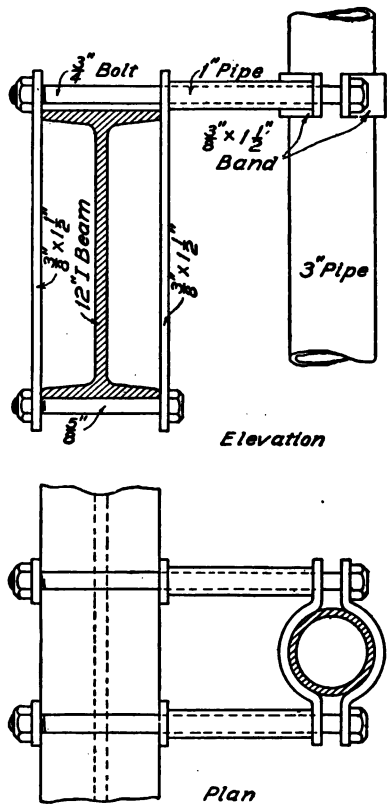


Fig. 32. Anchor for Riser.

Radiator Connections. Considerable ingenuity is exhibited by good fitters in arranging radiator connections. One should always study the end sought, and then provide the necessary means to secure that end. For example, on a floor at which the riser is anchored, almost any sort of radiator connection will answer, since expansion need not be provided for.

Where expansion takes place, swivels must be provided in the radiator connections, to allow for same. Fig. 33 shows a convenient way of taking off radiator connections from risers, any expansion

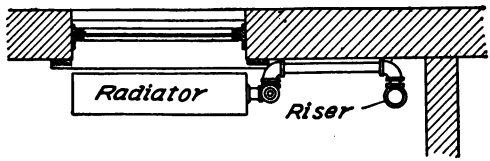


Fig. 33. Radiator Connections from Riser.

being taken up by the turning of the horizontal connection in the parallel nipples. The connection should of course pitch back toward

the riser, to drain freely. Where the expansion is considerable, this is difficult to accomplish unless the radiator is slightly raised.

When risers must be located along the same wall as that on which the radiator is placed, the swivels may be arranged as shown in Fig. 34.

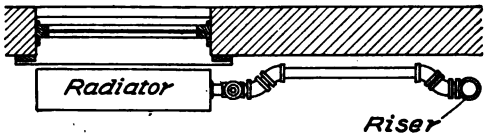


Fig. 34. Arrangement of Swivels when Risers are Located on the Same Wall as Radiator.

Radiators on the first floor have their connections made by angle valves with the pipes in the basement, to avoid running along the base-board. It is well to take the branch to the first-floor radiators from riser connections in the basement, rather than to cut into the mains for these branches. See Fig. 35.

COMPUTING RADIATION

Computing Direct Radiation. It is a perfectly simple matter to compute the amount of radiation required to heat a room, by finding the probable loss of heat per hour, and dividing this by the heat given off by a square foot of radiating surface in the same time.

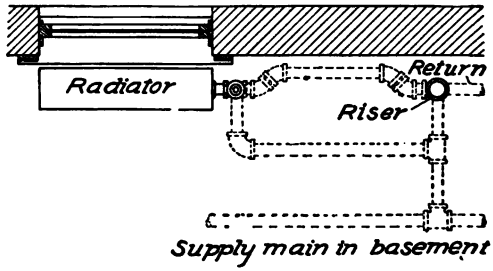


Fig. 35. Branch from Riser Connection in Basement.

Numerous tests have shown that an ordinary cast-iron radiator gives off approximately 1.6 heat units per hour per degree difference in temperature between the steam and the surrounding air. With low-pressure heating a square foot of direct radiation is commonly rated at about 250 H. U. Glass transmits about 85 heat units per square foot per hour, with 70° inside and 0° out; and walls of ordinary thickness may be reckoned as transmitting one-fourth as much heat.

The heat losses stated should be increased about 25 per cent for a north or west exposure, and about 15 per cent for an easterly exposure.

An allowance should be made for reheating rooms that are allowed to cool down slightly at night. This may be done most con-

veniently by adding to the loss of heat through walls and glass a number of heat units equal to 0.6 of the cubic contents of a room with two exposures, and 0.3 for a room with a single exposure.

To illustrate the method the following examples are given:

Suppose we have a room 16 feet square and 10 feet high, with two exposed walls facing respectively north and west, each having a window 3 feet 6 inches by 6 feet.

Exposure of room = (16+16)×10 =	320 sq. ft.
Glass surface = 2×21 sq. ft. =	42 " "
Net wall	278 sq. ft.
Equivalent glass surface (E. G. S.) of net wall = 278÷4 = Approx.	70 sq. ft.
Actual glass surface =	42 " "
Total E. G. S. Approx.	112 sq. ft.
Heat transmitted = 112 sq. ft. ×85 heat units×1.25 factor =	11,900 H. U.
Allowance for reheating = 0.6×cubic contents of 2,560 cu. ft. =	1,536 H. U.
Total heat loss to be made good by direct radiation	13,436 H. U.

This 13,436 heat units, divided by 250, the amount given off by one square foot of radiation in one hour, = 54 sq. ft. approximately, giving a ratio of 1 sq. ft. of radiating surface to 50 cubic feet of space.

Now take a room with one east exposure, the dimensions being 14 by 14 by 10 feet, with one window 4 by 6 feet.

Exposure =	140 sq. ft.
Glass =	24 " "
Net wall	116 sq. ft.
E. G. S. of net wall = ¼ of same =	29 " "
Add actual glass =	24 " "
Total E. G. S.	53 sq. ft.
Heat loss per hour = 67×85×1.15 =	5,180 H. U.
Add 0.3 of the contents to allow for reheating; 0.3×1,960 =	588 H. U.
Total heat loss	5,768 H. U.

This 5,768 heat units÷250 = 24 sq. ft. radiation required, giving a ratio of 1 to 82 cubic ft.

The following record form will be found advantageous:

1	2	3	4	5	6	7
Room	Exposure	Cubic Contents	Exposed Wall	Glass	Radiation (Computed)	Radiation (Plans)

After computations are made, radiation can be totaled and size of boiler can be determined and noted at bottom of sheet.

The loss of heat through roofs and through ceilings to unheated attic spaces above may be found by dividing the area of the roof by 10, and that of the ceiling by 20, to give the E.G.S. For a well-constructed plank roof, with paper or other material above, a dividing factor of 15 can be used for the roof.

It is hardly necessary, as a rule, to allow for the loss of heat through a first floor to the basement when the latter is well enclosed and contains steam and return mains or is otherwise kept at a moderate temperature.

Computing Direct-Indirect Radiation. The most common method of computing the amount of direct-indirect radiation required, is to ascertain, in the manner described, the direct radiating surface necessary, and add to it approximately 25 per cent; that is, if a direct radiator of 100 square feet were found to be necessary to heat a given room, a direct-indirect radiator of 125 square feet would be required.

Computing Indirect Radiation. To compute the amount of indirect radiation necessary to heat a given room, about the simplest method to grasp is to compute, first, the direct radiation required, as previously explained, and then add 50 per cent to this amount, since it happens that, under average conditions of 70° inside and 0° outside, practically 1½ times as much surface is required to heat a given space with indirect as with direct heating.

When a stated air supply is required, the loss of heat by ventilation must be computed, and a different method followed in ascertaining the amount of indirect radiation required. For example, take a 50-pupil schoolroom with the common compulsory allowance of 30 cubic feet of air per minute per pupil—equal to 1500 cubic feet per minute per room. Each cubic foot escaping up the vent flue at 70° F., when the outside temperature is zero, removes from the room 1¼ heat units; hence the total heat loss by ventilation per hour would be $60 \times 1500 \times 1\frac{1}{4} = 112{,}500$ heat units. A standard schoolroom has about 720 square feet of exposure, of which not far from 180 square feet is glass, leaving a net wall of 540 square feet, which, divided by 4, gives 135 square feet equivalent glass surface. This, added to the actual glass, gives 315 square feet E. G. S., which, in turn, multiplied by 85 heat units × a factor of 1.25 for north or west, gives a total heat loss by transmission of 33,470 heat units approximately.

The combined loss of heat by transmission and ventilation amounts to 145,970 H. U.

With the greater air-flow through indirect heaters used in schools, the heat emitted per square foot per hour should exceed somewhat the amount given off by indirect radiators in residence work—namely, 400 H. U. To be on the safe side. allow 450 H. U. The total heat

loss from the room, divided by this number, gives approximately 300 square feet as the surface required.

DUCTS, FLUES, AND REGISTERS

Areas of Ducts and Flues. The area of the cold-air connections with the benches or stacks of indirect radiators, are generally based on 1 to 1¼ square inches of area to each square foot of surface in the radiators.

The flues to the first floor should have 1½ to 2 square inches area to each square foot of surface; those to the second floor, 1¼ to 1½ square inches; and those to floors above the second, 1 to 1¼ square inches per square foot of radiation.

The sides and back of warm-air flues in exposed walls should be protected from loss of heat by means of a nonconducting covering, preferably ½ inch thick.

Flue Velocities. A fair allowance for flue velocities with indirect steam heating is 275 feet per minute for the first floor, 375 feet for the second, 425 feet for the third, and 475 for the fourth.

Registers. The net area of registers should be 10 to 25 per cent in excess of the area of the flue with which they are connected. The net area of a register is commonly taken as ⅔ the gross area; that is, a 12 by 15-inch register would have a net area of 120 square inches.

Registers in shallow flues must either be of the convex pattern, or be set out on a moulding to avoid having the body project into the flue and cut off a portion of its area.

Aspirating Heaters and Coils. To cause a more rapid flow of air in ventilating flues in mild weather, steam coils or heaters are used. These should be placed as far below the top of the vent flue as possible, for the higher the column of heated air, the greater the chimney effect. The smaller the flue in proportion to the volume of air to be handled, the larger should be the heater. If cast-iron indirect radiators are used, they may be rated to give off about 350 heat units per square foot per hour; coils may be rated to give off nearly double that number of heat units.

To illustrate how to compute the size of coil to be used, assume for example that 1,500 cubic feet per minute are to be removed

through a ventilating flue, the air to be raised 10° in temperature. Then

$$\frac{1{,}500 \text{ cu. ft. per min.} \times 60 \text{ min. per hour} \times 10° \text{ rise in temp.}}{55 \text{ heat units} \times 650 \text{ heat units per hour per sq. ft. of coil}} = 25.+ \text{ sq. ft. of coil required.}$$

(The number 55 is the number of cubic feet of air at 70° that 1 heat unit will raise 1° F.)

In order to work out important problems of this nature, it is necessary to consult a table giving flue velocities for different heights and for excesses of temperature of air in the flue over that out of doors. From such a table, knowing the height of the flue, its size, and the volume of air to be moved, it is readily seen how many degrees the air must be heated. The size of coil is then determined as above. The arrangement of an aspirating heater in a flue is shown in Fig. 36.

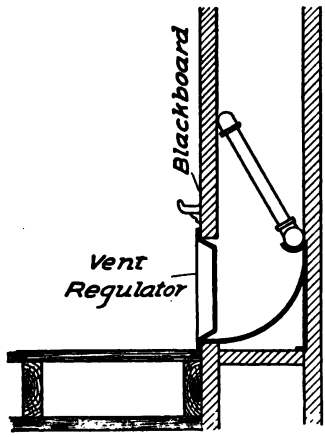


Fig. 35. Aspirating Regulator in Flue.

EXHAUST-STEAM HEATING

Buildings having their own power and lighting plant should be heated by exhaust steam, about 90 per cent of the steam that passes through the engines and pumps being available for this purpose.

A portion of this steam is used for heating the feed-water to the boilers. In a properly arranged system, very little fresh water need be supplied, since the condensation from the radiators, properly purified, is returned to the boilers.

To accomplish this purification, and to rid the steam of oil in order to prevent its coating the pipes and radiators, the steam is passed through a separator attached to the heater when all the steam is allowed to enter it, or through an independent separator when only a portion of the steam passes through the feed-water heater. Only about one-sixth of the exhaust steam in a given plant is required to heat the feed-water that must be supplied to the boilers to take the place of the steam used in the engines, therefore all the exhaust need

not enter the heater for the purpose of keeping up the proper temperature of the feed-water.

A type of heater with a coke fitter is shown in Fig. 37; while Figs. 38 and 39 show two methods of making connections, the first when all

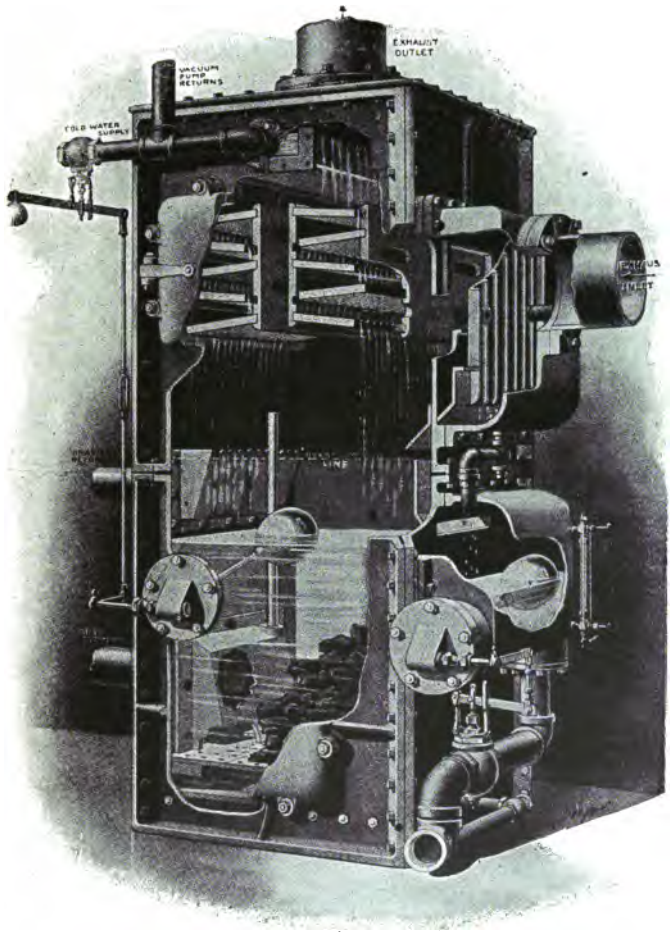


Fig. 37. Heater with Coke Fitter.

the steam is allowed to pass through the heater, the latter when only a portion of the exhaust from the engines is allowed to enter.

A very essential appliance used with exhaust-steam heating is the *pressure-reducing valve*, which makes good with live steam any de-

ficiency in exhaust that may occur. By adjusting the weight, any desired pressure, within limits, may be obtained.

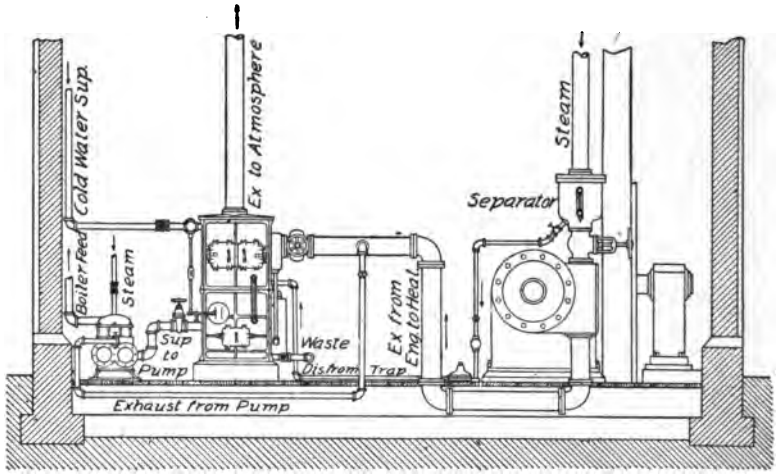


Fig. 38. Method of Making Connections when All the Steam is Allowed to Pass Through the Heater.

A *back-pressure valve* must be used with exhaust-steam heating, to regulate the pressure to be carried. It also acts as a safety-valve in case of over-pressure from any cause.

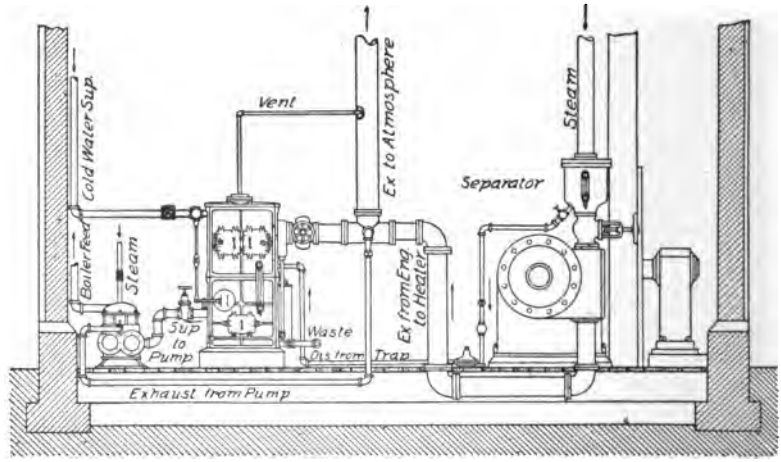


Fig. 39. Method of Making Connections when Only a Portion of Exhaust from Engine is Allowed to Enter.

Heating systems are sometimes arranged by bringing to them live steam to be reduced in the building to any desired pressure by a reduc-

ing valve. In such cases there is no back-pressure valve, therefore a safety-valve should be placed on the main to act in case of trouble with the reducing valve and prevent too great a pressure on the radiators.

A by-pass should be used in connection with all pressure-reducing valves, to provide for overhauling them. A steam gauge connected not less than 6 feet from the valve on the low pressure side is a necessary attachment.

With exhaust-steam heating, an exhaust head should be placed at the top of the vertical exhaust main, to condense, as far as possible, the steam passing through it.

The drip pipe from the exhaust should be connected with the drip tank; or, if the exhaust has been passed through a first-class separator, it may, if desired, be returned to the feed-water heater.

When a closed type feed-water heater is used (see Fig. 40), a separate tank must be provided for the returns from the heating systems. High-pressure drips are trapped to this tank. In the case of the heater shown in Fig. 37, the live-steam returns are trapped to it. A common type of trap is shown in section in Fig. 41. In the position shown, the float or bucket hinged as shown, is held up by the buoyancy of the water, and keeps the valve at the upper end of the spindle in contact with the seat, preventing the escape of steam entering with the water through the inlet. The water, rising around the bucket, overflows it and overcomes its buoyancy, causing it to fall and open the valve, the steam pressure on the water then forcing it out of the bucket until a point is reached where

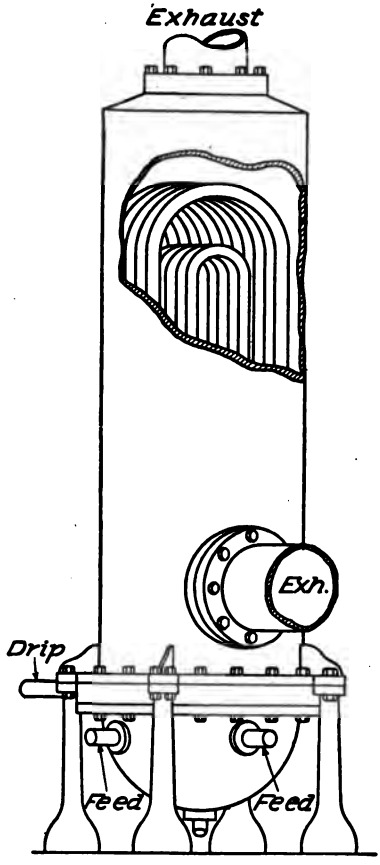


Fig. 40. Closed Type Feed Water Heater.

the buoyancy of the bucket again comes into play and closes the valve until the action is again repeated.

An extremely simple form of float trap is shown in Fig. 42, the hollow float raising the spindle and valve, permitting water to escape,

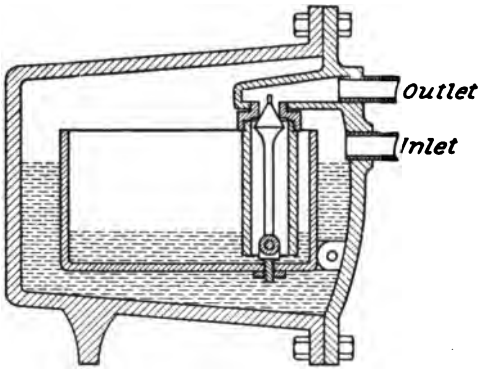


Fig. 41. Common Type of Trap

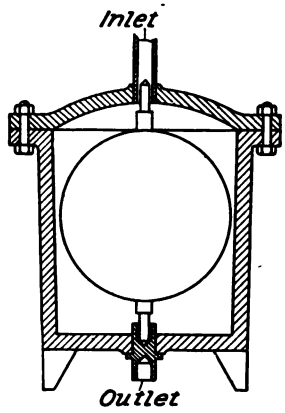


Fig. 42. Float Trap

but falling and thus closing the outlet when the level reaches a point too low to cause the ball to float, thus preventing the escape of steam.

Special forms, known as *return traps*, are used in small plants for returning to the boiler the condensation from the heating system.

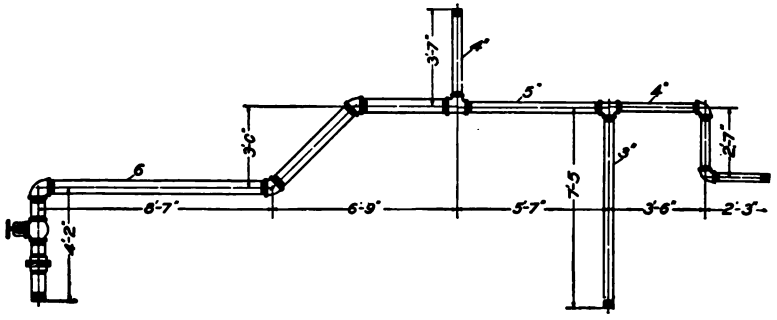


Fig. 43. Dimensioned Sketches for Cutting Pipe

In large installations of 15,000 square feet and above, it is advantageous to run boilers at high pressure and reduce for heating, on account of maintaining a uniform pressure on the heating system. In this case, two pressure reducing valves should be installed, one to take care of maximum heating requirements, and the other for

average requirements. This reduces the wear on the large valve very materially.

MODIFIED SYSTEMS OF STEAM HEATING

It is beyond the scope of this course to go into the details of the various modified or patented systems of steam circulation, yet it seems advisable to point out the essential features of certain of these systems. The Webster and Paul Systems will be found described in Part III of the Instruction Paper on Heating and Ventilation.

Thermograde System. With this two-pipe system air valves are omitted; the supply valve on each radiator is of a special construction designed to be set to admit quantities of steam under different conditions—to fill the radiator $\frac{1}{4}$, $\frac{1}{2}$, $\frac{3}{4}$, or entirely full of steam. On the return end of each radiator is placed a so-called *auto-valve*, designed to permit the escape of air and water into a return pipe open to the atmosphere at the top. In the case of large buildings the water flows by gravity to a tank, from which it is pumped to the boilers.

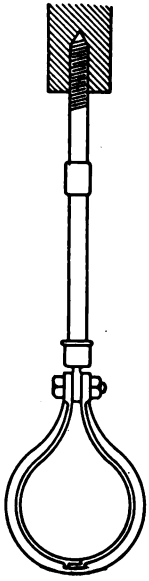


Fig. 44. Hanger

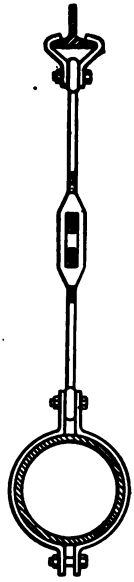


Fig. 45. Adjustable Hanger for Large Pipe

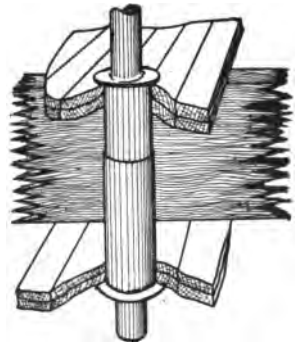


Fig. 46. Sleeve for Encasing Pipe

Some of the advantages claimed for this system are:—Absence of air-valves and air-lines; control of the heat emitted, by means of the special controlling valve at the supply end of each radiator. The piping is the same as for ordinary gravity systems.

Vapor System. This system is designed, as its name implies,

to work on a very low pressure. The radiators, preferably of the hot-water type, must have considerably more surface than with low-pressure steam heating. A special valve is placed at the supply end of each radiator, designed to admit any desired volume of steam.

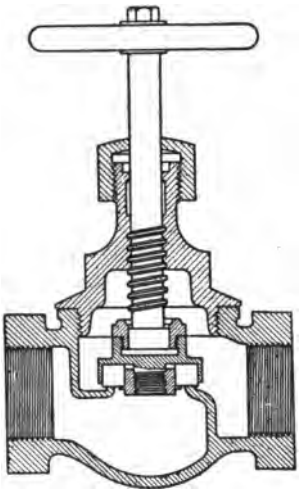


Fig. 47. Globe Valve.

A little trap or water-seal fitting is connected with the return end of each radiator, a small hole being provided above the water line to permit the escape of air. All returns are joined in the basement and discharge to an open water column alongside the boiler, any steam in the returns being condensed by passing into a coil provided for the purpose.

No safety valve is required with this system. In case of an excess of pressure in the boiler, the water is backed out into the column above mentioned; a float is raised; and dampers are closed.

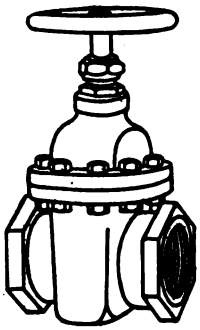


Fig. 48. Gate Valve.

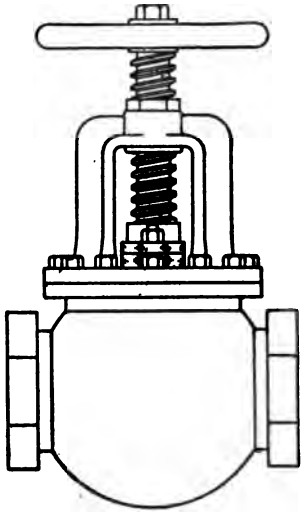


Fig. 49. Iron Body Globe Valve.

The advantages claimed are:—Complete control of the heat given off by the radiators by means of the special regulating valve on each; absolute safety; small pipes; absence of air-valves.

Mercury Seal Vacuum Systems. In one of these systems, commonly used with gravity-return apparatus, air-valves similar to those shown in Fig. 55 are placed on the radiators, and the air-lines connected with a main line discharging through a mercury seal or column, the function of which is to seal the end of the pipe and prevent the entrance of air after the air from the system has been expelled by

raising the steam pressure. In another mercury seal system, air-valves are omitted and "retarders"—so called—are placed at the return ends of radiators.

With a tight job of piping when the air in the system has once been got rid of, the plant may be run for some time—or until air leaks in again—at a pressure less than the atmosphere and with radiators at temperatures corresponding to those of hot-water radiators.

Among the claims made for this system are:—Wide range of temperature in the radiators, secured by varying the degree of vacuum; the advantage of a hot-water heating system without large radiators, since steam under pressure can be carried in the radiators in cold weather.

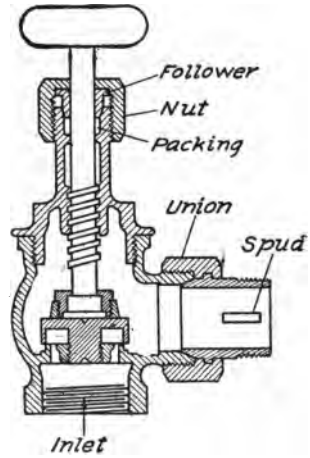


Fig. 50. Radiator Angle Valve

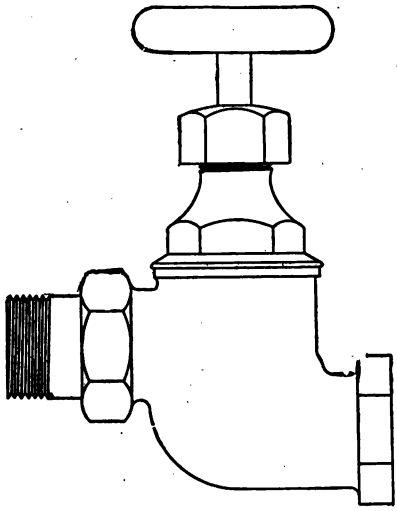


Fig. 52. Radiator Offset Valve.

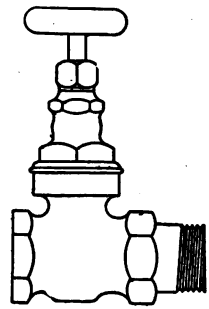


Fig. 51. Radiator Straightway Valve

PIPE AND FITTINGS

Pipe. Pipe for heating systems should be made of wrought iron or mild steel. Sizes up to 1¼ inches diameter inclusive, are butt-welded and proved to 300 pounds' pressure; above that size they are lap-welded and tested to 500 pounds' pressure.

TABLE VIII

Standard Weight Pipe Dimensions and Data

Diameters (Inches)			Areas (Square Inches)			Miscellaneous						
Nominal Diameter	Actual External Diameter	Actual Internal Diameter	External Area	Internal Area	Area of Metal	Thickness of Metal	Linear Feet per Square Foot of External Surface	Linear Feet to Contain One Cubic Foot	Pounds of Water per Linear Foot	Nominal Weight of Pipe per Foot (Pounds)	Threads per Inch	Taper of Threads per Inch of Screw
⅛	.405	.269	.1288	.0568	.0720	.068	9.44	2,500.	.024	.241	27	¾
¼	.540	.364	.2290	.1041	.1249	.088	7.075	1,385.	.044	.42	18	¾
⅜	.675	.493	.3578	.1909	.1669	.091	5.657	751.5	.082	.559	18	¾
½	.840	.622	.5542	.3039	.2503	.109	4.502	472.4	.132	.837	14	¾
¾	1.050	.824	.8659	.5333	.3326	.113	3.637	270.	.23	1.115	14	¾
1	1.315	1.047	1.3581	.8609	.4972	.134	2.908	166 9	.378	1.668	11½	¾
1¼	1.660	1.380	2.1642	1.4957	.6685	.140	2.301	96 25	.648	2.244	11½	¾
1½	1.900	1.610	2.8353	2.0358	.7995	.145	2.01	70.65	.883	2.678	11½	¾
2	2.375	2.067	4.4301	3.3558	1.074	.154	1.611	42.36	1.454	3.609	11½	¾
2½	2.875	2.467	6.4918	4.7800	1.712	.204	1.328	30.11	2.072	5.739	8	¾
3	3.500	3.066	9.6211	7.3827	2.238	.217	1.091	19.49	3.202	7.536	8	¾
3½	4.000	3.548	12.566	9.886	2.680	.226	.955	14.56	4.295	9.001	8	¾
4	4.500	4.026	15.904	12.730	3.174	.237	.849	11.31	5.517	10.665	8	¾
4½	5.000	4.506	19.635	15.960	3.675	.246	.765	9.03	6.908	12.34	8	¾
5	5.563	5.045	24.306	19.985	4.321	.259	.629	7.20	8.668	14.502	8	¾
6	6.625	6.065	34.472	28.886	5.586	.280	.577	4.98	12.52	18.762	8	¾
7	7.625	7.023	45.664	38.743	6.921	.301	.501	3.72	16.79	23.271	8	¾
8	8.625	7.981	58.426	50.021	8.405	.322	.444	2.88	21.66	28.177	8	¾
10	10.750	10.018	90.763	78.822	11.94	.366	.355	1.80	34.17	40.065	8	¾
12	12.750	12.000	127.68	113.09	14.59	.375	.293	1.235	49.03	48.985	8	¾

Circumference = Diameter × 3.1416.
1 cu. ft. = 7½ gallons.
1 gallon = 231 cu. inches.

1 cu. ft. of water weighs 62.4 lbs.
1 gallon of water weighs 8⅓ lbs.

Pipe is shipped in lengths of 16 to 20 feet, threaded on both ends and fitted with a coupling at one end.

It is well, as a rule, to have pipes 2½ inches in diameter and larger cut in the shop from sketches. These should give the distances from end to center, or center to center, and should state the size and kind of valves, whether flanged or screwed fittings are to be used, and in a general way should follow Fig. 43.

The dimensions of standard pipe are given in Table VIII.

NOTES ON WROUGHT-IRON PIPE

(Furnished by the Crane Company, Chicago, Ill.)

WROUGHT-IRON PIPE:—This term is now used indiscriminately to designate all butt- or lap-welded pipe, whether made of iron or steel.

MERCHANT PIPE:—This term is used to indicate the regular wrought pipe of the market, and such orders are usually filled by the shipment of soft steel pipe. The weight of merchant pipe will usually be found to be about five per cent less than card weight, in sizes ⅛-inch to 6-inch, inclusive; and about ten per cent less than card weight, in sizes 7-inch to 12-inch, inclusive.

FULL-WEIGHT PIPE:—This term is used where pipe is required of about card weight. All such pipe is made from plates which are expected to produce pipe of card weight; and most of such pipe will run full card to a little above card, but, owing to exigencies of manufacture, some lengths may be below card, but never more than five per cent.

LARGE O. D. PIPE:—A term used to designate all pipe larger than 12-inch. Pipe 12-inch and smaller is known by the nominal internal diameter, but all larger sizes by their external (outside) diameter, so that "14-inch pipe," if ⅜ inch thick, is 13¼-inch inside, and "20-inch pipe" of same thickness is 19¼-inch inside.

The terms "Merchant," or "Standard pipe," are not applicable to "Large O. D. pipe," as these are made in various weights, and should properly be ordered by the thickness of the metal.

When ordering large pipe threaded, it must be remembered that ¼-inch metal is too light to thread, $\frac{5}{16}$-inch being minimum thickness.

Orders for large outside diameter pipe, wherein the thickness of metal is not specified, are filled as follows:

Fourteen, fifteen, and sixteen inch, O. D., $\frac{5}{16}$-inch or ⅜-inch metal.

Larger sizes, ⅜-inch metal.

This pipe is shipped with plain ends, unless definitely ordered "threaded."

EXTRA STRONG PIPE:—This term designates a heavy pipe, from ⅛-inch to 8-inch only, made of either puddled wrought iron or soft steel. Unless directed to the contrary, steel pipe is usually shipped. If wrought-iron pipe is required, use the term, "Strictly Wrought-Iron Extra Strong Pipe." Extra strong pipe is always shipped with plain ends and without couplings, unless instructions are received to thread and couple, for which there is an extra charge.

This term when applied to pipe larger than 8-inch, is somewhat indefi-

nite, as 9-, 10-, and 12-inch is made both $\frac{7}{16}$ and $\frac{1}{2}$ inch thick. Pipes $\frac{1}{2}$ inch thick are carried in stock, and furnished on open order.

DOUBLE EXTRA STRONG PIPE:—This pipe is approximately twice as heavy as extra strong, and is made from $\frac{1}{2}$ to 8 inches, in both iron and steel. It is difficult, however, to find any quantity in "Strictly Wrought-Iron," and the stock carried is usually soft steel. This pipe is shipped with plain ends, without couplings, unless ordered to thread and couple, for which there is an extra charge.

Fittings. For low-pressure heating systems, standard weight cast-iron screwed fittings are used on pipes up to 7 inches or 8 inches diameter. On larger pipes it is customary to use standard flanged fittings. Flange unions should be placed at intervals in the pipes when screwed fittings are used, to provide for readily disconnecting them in case of alterations or repairs.

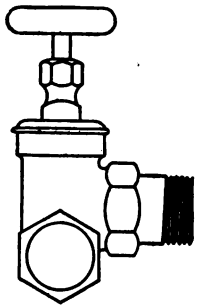


Fig. 53. Radiator Valve.

Pipe grease or various compounds are used in "making up" the joints. This material should be applied to the male threads only. When the threads of the fittings are coated with it, as is commonly done, the compound is pushed into the fitting when the pipe is screwed in, and, becoming disengaged, is likely to cause trouble later by clogging pipes, etc. For flange fittings it is the practice with many fitters to use inside gaskets, so called, cut to come just inside the bolts.

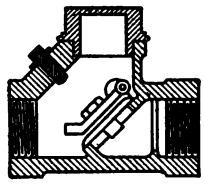


Fig. 54. Swing Check Valve.

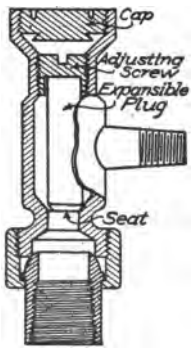


Fig. 55. Air Valve.

To describe a tee, always give the dimensions of the "run" first and the outlet last; for example, a tee 6 inches at one end, 5 inches at the other, with an outlet at the side $3\frac{1}{2}$ inches, would be known as a 6 by 5 by $3\frac{1}{2}$ tee.

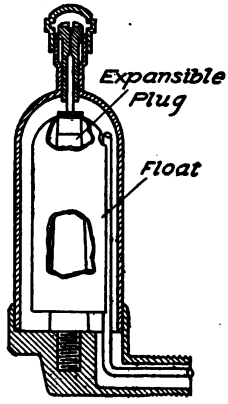


Fig. 56. Air Valve.

A tee with the outlet larger than the openings on the run, is known

as a *bullhead* tee. Tees with all three openings of the same size are known as *straight* tees.

It is far better to use reducing sockets or reducing elbows and tees, in place of straight tees with bushings.

Hangers. Pipes up to 4 inches diameter inclusive are commonly suspended by malleable-iron hangers, one type of which is shown in Fig. 44, with a gimlet point on the rod, a beam clamp being substituted

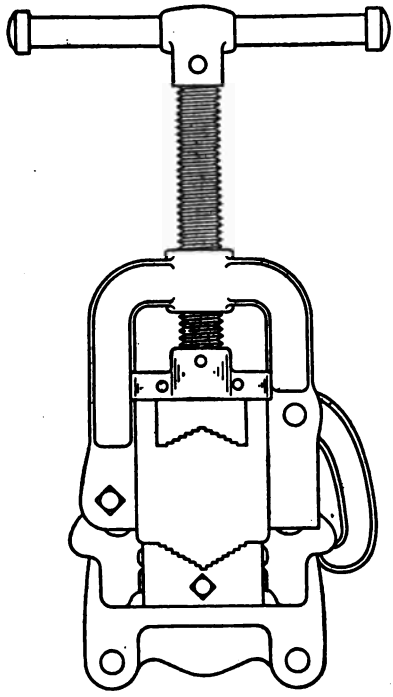


Fig. 57. Pipe Vise.

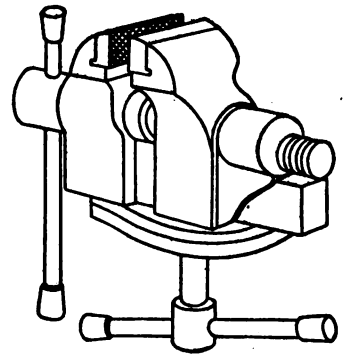


Fig. 58. Flat Jaw Vise.

when I-beams are used in place of floor timbers. One form of adjustable hanger for large pipes is shown in Fig. 45.

Sleeves, etc. Where pipes pass through floors and partitions, they are encased in tubes with plates at floor and ceiling or at walls, as the case may be. One type of these sleeves is shown in Fig. 46.

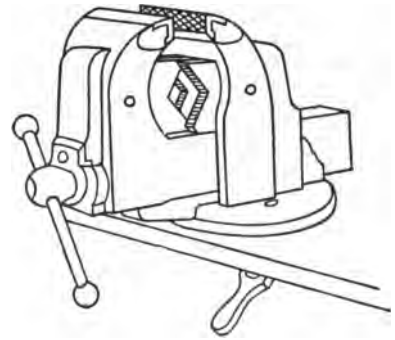


Fig. 59. Combination Vise.

Where branches from risers pass through partitions, it is often necessary to use sleeves of elliptical shape to provide for the expansion

of the risers. Sleeves for mains passing through basement walls are generally made of pieces of wrought-iron pipe of the proper length, the diameter of the sleeves to be not less than $\frac{1}{2}$ inch greater than the pipe diameter if covering is omitted in walls, and $2\frac{1}{2}$ inches greater if covering is continuous along the pipe.

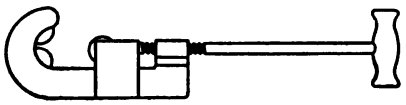


Fig. 60. Pipe Cutter.

When sleeves are placed in plastered walls, they should project a slight distance beyond the face of the plaster. When ceiling plates are made fast to risers, they should be placed at least $\frac{3}{8}$ inch down from the ceilings, so that, when the riser expands, the ceiling plate will not be forced into the plaster.

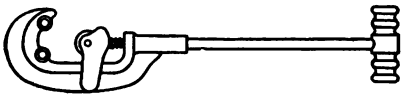


Fig. 61. Pipe Cutter.

Valves. Valves for basement piping are commonly *globe* or *gate* pattern, with rough bodies and plain iron wheels (Figs. 47 and 48). Brass or composition body valves, with screwed tops, are generally used up to 2-inch size inclusive; and iron body valves, with bolted tops, above that size (see Figs. 48 and 49). Both are made with renewable discs or seats.

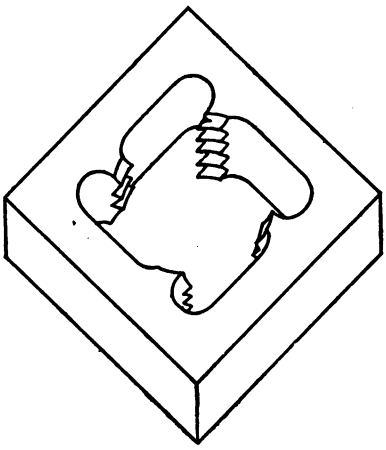


Fig. 62. Solid Die.

It is largely a matter of preference which type of valve shall be used, though of course the straightway gate valves interpose the least resistance to the flow of steam or water.

When the radiators are but little above the water line in the boiler, gate valves are frequently used on the returns to insure an easy flow of the water.

It seems hardly necessary to point out that a globe valve should be connected in the pipe with its stem horizontal, to avoid the water pocket which occurs when the stem is vertical; nevertheless fitters frequently overlook this point.

Several patterns of radiator valves are shown in Figs. 50, 51,

52, and 53. These valves are of brass or composition, rough body nickel-plated, have wood wheels, and are provided with a union. The angle valves are commonly used on first-floor radiators, those on floors

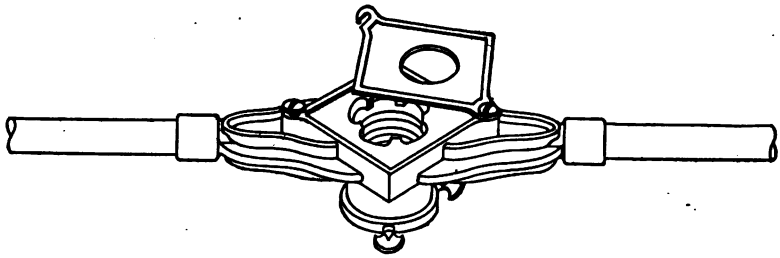


Fig. 63. Stock for Solid Dies.

above having offset or corner offset, offset globe, or straightway gate valves, according to the type of radiator and the arrangement of connections to provide for expansion.

In public buildings, the wheels are often omitted and lock-shields substituted, the valves being operated by a key.

A *swinging-check* valve is shown in Fig. 54. This type, if prop-

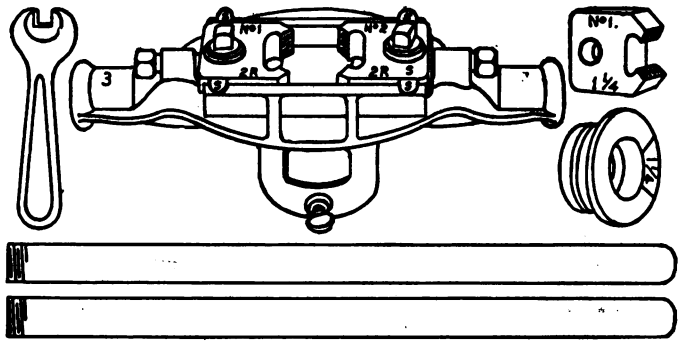


Fig. 64. Adjustable Die and Stock.

erly designed, works the easiest of any, and should be used in preference to other types when radiators are placed but little above the water line in the boiler.

Air-Valves. Numerous patterns of air-valves are on the market, some, like Fig. 55, in a general way, being fitted with a union for air-line connections leading to a convenient point of discharge in the basement. Such valves prevent the escape of steam, because of the expansion of the composition plug, which closes the opening when steam

comes in contact with it. Air and cold water, however, are permitted to escape.

The general type of air-valve shown in Fig. 56 is frequently used, many modifications of this valve having been manufactured. These

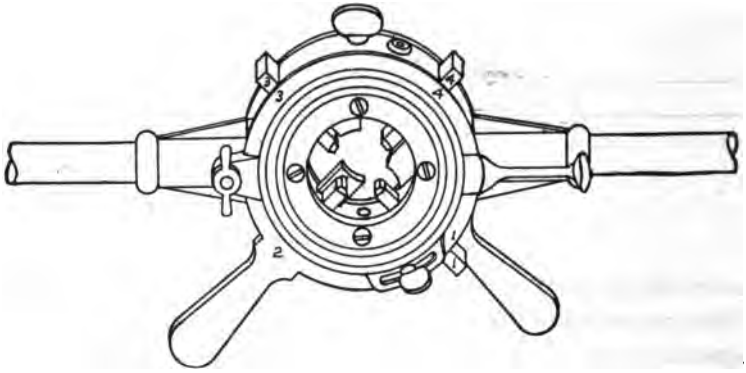


Fig. 65. Adjustable Die and Stock.

valves, as a rule, have no air-line connections, but discharge their air into the rooms; a somewhat objectionable feature. They close when steam enters them; and if water finds its way in, the float is raised and closes the outlet.

Air-valves for direct radiators have a very small opening for the

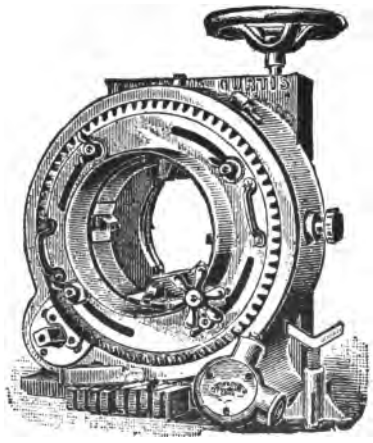


Fig. 66. Hand Power Pipe Machine.

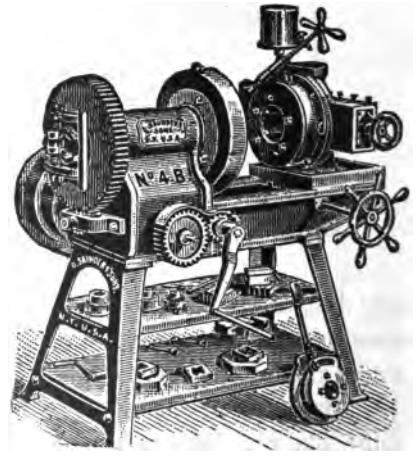


Fig. 67. Belt Power Pipe Machine.

discharge of air, scarcely larger than a pin-hole; and while these do very well for small units, they are not satisfactory for large coils or for

large groups of indirect radiators, because of the excessive time required to relieve them from air. For such heating surfaces, a type of air-valve with a much larger opening should be selected, to provide for venting the radiators or coils more quickly.

Several types of vacuum air-valves have been invented, designed to permit the escape of air from the radiators, but to prevent its reentry. If they remain tight, the steam heating system may be run in mild weather with a pressure below that of the atmosphere, and the radiator kept at a temperature below 200°.

Fig. 68 *a*. Hand Power Pipe Machine.

Pipe-Fitting Tools.—Vise and Bench. When a job is started, the first things needed are vise and bench. The latter should be firmly constructed, and rigidly held in place, the vise to be firmly secured to it by through bolts.

On a good-sized piece of work, it is well to have both a *pipe vise* and a *flat-jaw vise*, these being illustrated in Figs. 57 and 58. A heavy cover should be furnished over the screw of the flat-jaw vise, to provide a bearing for bending pipe, the end of which is passed through a ring bolted to the bench.

Fig. 59 illustrates a combination of the two vises shown in Figs. 57 and 58, making a very useful tool.

Pipe Cutters. There are several kinds of pipe cutters on the market, made with one or more cutting wheels held in a frame. All makes of cutters are operated in practically the same way, by forcing the cutting wheels into the pipe by means of a screw handle. One- and three-wheel cutters are shown in Figs. 60 and 61. The one-wheel

cutters are made in sizes for $\frac{1}{8}$-inch to 3-inch pipe; and the three-wheel cutters, for $\frac{1}{8}$-inch to 8-inch pipe.

Stocks and Dies. The several forms of dies and stocks on the market may be divided into two classes—the *solid die* and the *adjustable die.* The solid die is shown in Fig. 62, and is used for cutting both right-hand and left-hand threads. The stock in which solid dies are used is shown in Fig. 63. Adjustable dies and stocks are shown in Figs. 64 and 65. These dies may be adjusted to cut a deep or a shallow thread. It is necessary at times to cut such threads, as the fittings made by different manufacturers are not always tapped alike. To make good joints, the threads must make up tight when they are screwed into the fitting.

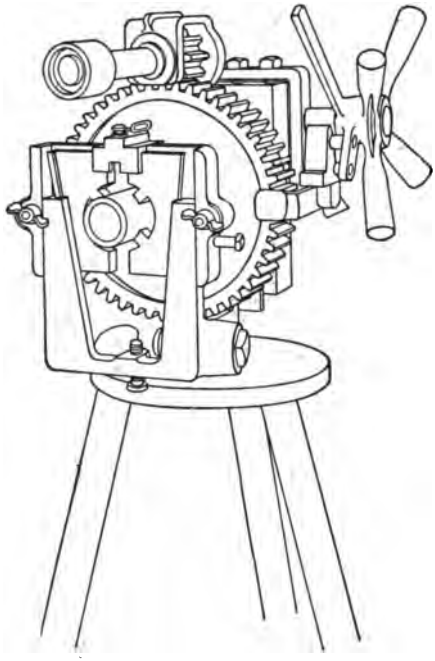


Fig. 68 *b.* Hand Power Pipe Machine.

Table IX shows the approximate distance pipes must be screwed into fittings to make a tight joint.

TABLE IX

Proper Distance to Screw Pipes into Fittings

$\frac{1}{4}$, $\frac{3}{8}$, and $\frac{1}{2}$	inch	pipe	should	be	screwed	into	fittings	approximately	$\frac{3}{8}$	in.
	$\frac{3}{4}$	"	"	"	"	"	"	"	"	$\frac{1}{2}$	"
	1	"	"	"	"	"	"	"	"	$\frac{11}{16}$	"
$1\frac{1}{4}$ and	$1\frac{1}{2}$	"	"	"	"	"	"	"	"	$\frac{5}{8}$	"
	2	"	"	"	"	"	"	"	"	$\frac{3}{4}$	"
$2\frac{1}{2}$ and	3	"	"	"	"	"	"	"	"	$\frac{7}{8}$	"
$3\frac{1}{2}$ and	4	"	"	"	"	"	"	"	"	1	"
5 and	6	"	"	"	"	"	"	"	"	$1\frac{1}{8}$	"
	7	"	"	"	"	"	"	"	"	$1\frac{1}{4}$	"
8 and	9	"	"	"	"	"	"	"	"	$1\frac{3}{8}$	"
10 and	12	"	"	"	"	"	"	"	"	$1\frac{1}{2}$	"

In all forms of stocks, whether for solid or adjustable dies, a bushing or guide must be used in the stocks to guide the dies straight onto the pipe. It is necessary that the guides for the different sizes of pipe should fit each size of pipe as closely as will allow the guide to revolve on the pipe freely. The guides should fit the stock as tightly as possible, or a crooked thread will very likely be cut.

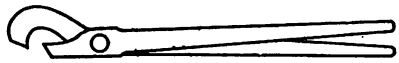


Fig. 69. Pipe Tongs.

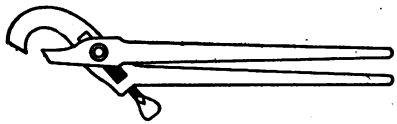


Fig. 70. Adjustable Pipe Tongs.

Plenty of good lard oil or cotton-seed oil should be used when cutting pipe. The dies must be sharp, to make good joints; and when they are changed in the stocks from one size to another, all chips of iron and dirt should be cleaned off the dies and out of the stocks, as a small chip under dies, especially under one of a set of adjustable dies, will either cut a crooked thread or strip it.

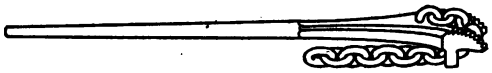


Fig. 71. Chain Tongs.

Stocks are made in sizes from $\frac{1}{8}$ inch to 4 inches. The small-size stocks and dies commonly carried in pipe-fitters' kits are made to thread pipe from $\frac{1}{8}$ inch to 1 inch inclusive, right-and left-hand; and a larger size to thread pipe from 1 inch to 2 inches inclusive, right- and left-hand. A larger-size stock is used to cut pipes over 2 inches in diameter.

There are a number of hand-power pipe machines on the market,

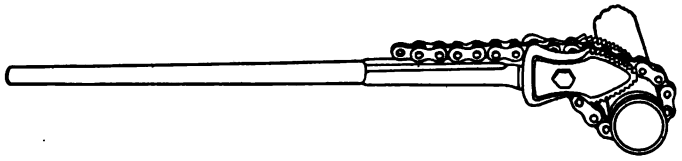


Fig. 72. Chain Tongs.

which are very convenient especially for cutting and threading pipe $2\frac{1}{2}$ inches and over. Several makes are shown in Figs. 66, and 68 *a* and 68 *b*.

Pipe Tongs. Plain tongs, like all other tools, must be kept sharp and in good order, to do good work. Many fitters object to tongs because they have to be sharpened very often, and also because they

have to carry at least one pair of tongs for each size of pipe; they prefer an adjustable wrench which will fit several different sizes of pipe. There is one advantage in the tongs; that is, they can be worked in places where it would be impossible to use a wrench, such as making up pipe in coils, close corners, etc. Tongs should be made in such a way that when they are on the pipe, the handles will come close enough together to allow them to be gripped in one hand (see Fig. 69).

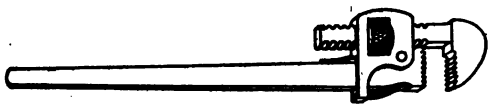


Fig. 73. Pipe Wrench.

Adjustable tongs (Fig. 70) are made to fit several sizes of pipe, the most common sizes used being for ⅜-inch to 1-inch to 2-inch, and for 2½-inch to 4-inch.

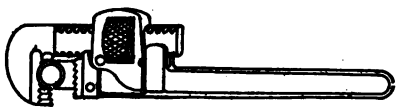


Fig. 74. Pipe Wrench.

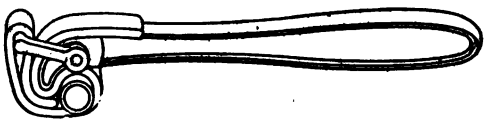


Fig. 75. Wrench for Brass or Nickle-Plated Pipe.

Chain tongs are made in all sizes and in several forms for from 1-inch up to 16-inch pipe. Some makers furnish tongs with the handle and jaws in one piece. Others have the jaws removable. Still others have the jaws so arranged that they can be removed and reversed. See Figs. 71 and 72.

Fig. 76. Wrench for Brass or Nickle-Plated Pipe.

Pipe Wrenches. Several types of adjustable wrenches are shown in Figs. 73 and 74. These wrenches will do good work if used as wrenches on the size pipe they are intended for. Some men who have little regard for tools use on a 2-inch pipe, for example, a wrench which is made to take, say, not over 1-inch pipe, the jaw of the wrench being extended as far as possible, and probably being held by only a few threads of the adjusting screw, a piece of pipe 2 or 3 feet long often being used on the handle of the wrench to

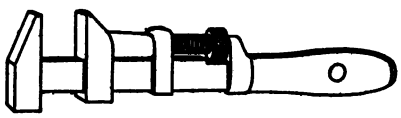


Fig. 77. Monkey Wrench.

increase the leverage. After such usage, the wrench is of little value. At times men will use wrenches in such a way as to make the strain come on the side, with the result that the wrench is badly strained if not broken.

Fig. 78. Open-End Wrench.

The above described wrenches are used on wrought-iron pipe. For brass or nickel-plated pipe, wrenches like those shown in Figs. 75 and 76 should be used; otherwise the pipe will be marred and rendered unfit for use in connection with first-class work.

One of the handiest all-round tools is the *monkey wrench*, shown in Fig. 77. *Open-end* wrenches, illustrated in Figs. 78 and 79, are very handy tools, especially for use on flange fittings. Wrenches for lock-nuts are made about the same as above, only they are larger.

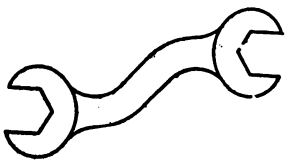


Fig. 79. Open-End Wrench.

The *return-bend wrench* is a very handy tool, and can be made by any good blacksmith. It is used principally on coil work, and is made of heavy bar iron, as shown in Figs. 80 and 81, in which two forms of this type of this wrench are shown.

Another handy tool is what is sometimes called, for want of a better name, a *spud wrench*. This is simply a piece of flat iron about

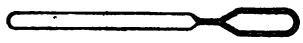


Fig. 80. Return-Bend Wrench.

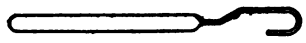


Fig. 81. Return-Bend Wrench.

10 inches long and made to fit the spuds of the unions of different sizes of union radiator valves and elbows (see Fig. 82).

Pliers. For small work, pliers may be used to advantage. Common and adjustable types are shown in Figs. 83 and 84.

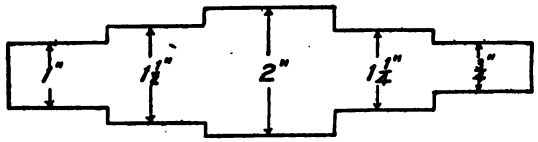


Fig. 82. Spud Wrench.

Drills, Reamers, and Taps. Pipe drills, illustrated in Fig. 85, are made slightly smaller for a given size than the taps illustrated in Fig. 86. A reamer like the one shown in Fig. 87 should be used to

start the tap, which should never be hammered in order to start the threads.

Fig. 88 shows a combined drill, reamer, and tap. Fig. 89 shows a pipe reamer for taking the burr from the ends of pipes.

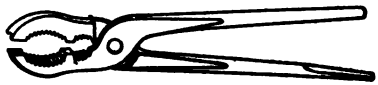


Fig. 83. Common Pliers.

Fig. 84. Adjustable Pliers.

A *ratchet drill* is illustrated in Fig. 90 and a *breast drill* in Fig. 91. Fig. 92 shows a handy tool for drilling pipe flanges which from any cause cannot be drilled in the shop.

Fig. 85. Pipe Drill.

Figs. 93, 94, 95, and 96 show *cold, cape, diamond point,* and *round-nose* chisels respectively.

A good pattern *pean hammer* is shown in Fig. 97 *a*; and a *brick hammer* is represented by Fig. 97 *b*.

Miscellaneous. Every fitter's kit should contain inside and outside *calipers*; a good set of *bits* ¼-inch to 1-inch; *bit stock*; *augers* 1¼-inch to 2-inch; *saws*; *files*; *plumb-bob*; *gimlet*; *lamp*; *oil can*; *steel square*; *tape measure*; etc.

HOT-WATER HEATING

Heaters. Hot-water heaters—or "boilers," as they are sometimes miscalled—are so nearly like the cast-iron steam boilers previously illustrated, that it is unnecessary further to describe them here.

Some makers use the same patterns for both steam boilers and hot-water heaters, while others use a higher boiler for steam, giving more space above the water line.

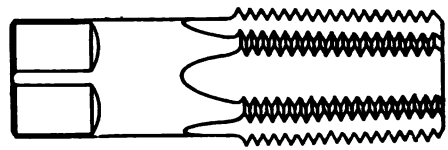


Fig. 86. Pipe Tap.

Practically the same rules should be followed in selecting a hot-water heater as those laid down for steam boilers. Although a hot-water heater is a trifle more efficient than a steam boiler—that is, more of the heat in the coal is transferred to the water, owing to the temperature of the latter being 40 degrees or more lower than in a steam boiler—nevertheless, practically the

same size of hot-water heater or steam boiler is required to heat a given space.

It is well to equip the heater with a regulator, of which a number of good ones are manufactured, in order to control the drafts by variations in the temperature of the water, the regulator being set to maintain any desired temperature in the flow pipe.

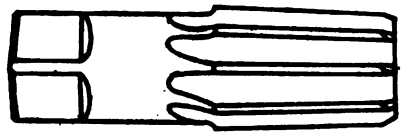


Fig. 87. Reamer.

Capacity of Heaters. Hot-water heater capacities are based, as a rule, on an average water temperature of 160° in the radiators, when placed in rooms to be kept at 70° F.

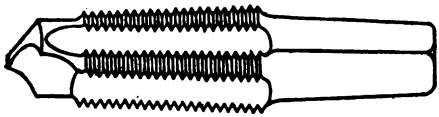


Fig. 88. Combined Drill, Reamer and Tap.

If the *closed-tank system* is used, the radiator temperatures may be 220° to 230° or more; hence, if any attention is to be given to the manufacturers' heater rating, the radiation must be reduced to the equivalent radiation in heat-emitting capacity of radiators at 160°.

This is very easily computed, since the heat given off by a radiator is proportional to the difference in temperature between the water in the radiator and the air surrounding it. This, in the first case, is 160° less 70°,

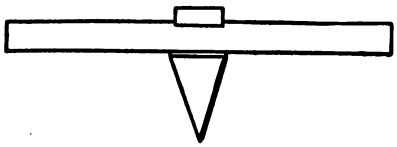


Fig. 89. Pipe Reamer for Taking the Burr from Ends of Pipe.

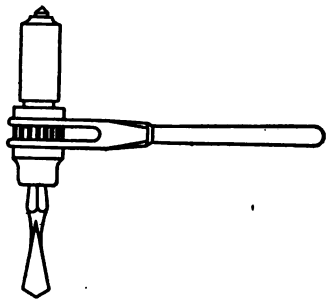


Fig. 90. Ratchet Drill.

or 90°; and in the other case, say, 225° less 70°, or 155°; that is, one foot of radiating surface at 225° will give off $\frac{155}{90}$ of the heat given off at 160°; therefore, a job with 900 square feet, for example, at 225° would be equivalent in heating power to $\frac{155}{90} \times 900 = 1550$ square feet at 160°, and a boiler with the higher rating would be required

It is always well to check the boiler rating as explained under "Steam Heating," except that in hot-water heating only 150 heat units are allowed per hour per square foot of radiating surface.

Fig 91. Breast Drill.

Of the heat given off by the coal, it is safe to assume that 8000 heat units per pound are transferred to the water in the heater.

Suppose there are 900 square feet of radiation on the job. Add $\frac{1}{3}$ to cover the loss of heat from pipes; total = 1200 square feet. Assume that in coldest weather 5 pounds of coal are burned per hour on each square foot of grate; that is, $5 \times 8000 = 40{,}000$ heat units are transferred to the water in the heater. The heat given off per hour by the radiators and pipes is $1200 \times 150 = 180{,}000$ heat units. This, divided by 40,000, the heat utilized per square foot of grate, equals $4\frac{1}{2}$ square feet of grate required.

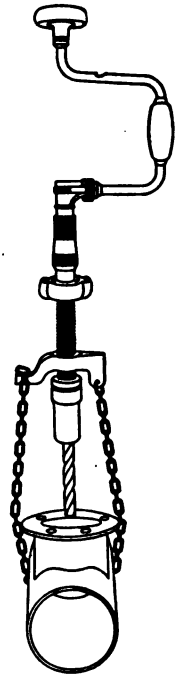


Fig. 92. Tool for Drilling Pipe Flanges.

Some judgment is necessary in assuming the rate of combustion; but this varies from about 3 pounds per square foot of grate per hour in small heaters, to 7 or 8 in larger ones, operated by a regular attendant.

HOT-WATER RADIATORS AND VALVES

Hot-water radiators have top and bottom nipple connections, as shown in Fig. 31, Part II (Heating and Ventilation). A hot-water

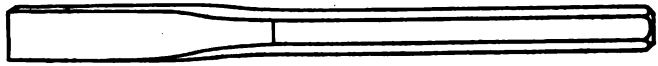


Fig. 93. Cold Chisel.

radiator may be used for steam, but a steam radiator cannot be used for hot water. The valve may be placed at the top or the bottom—it

matters little which; it is, however, more convenient, though more unsightly, at the top. The circulation will be practically as good when the valve is located at the bottom. One valve is all that is necessary,

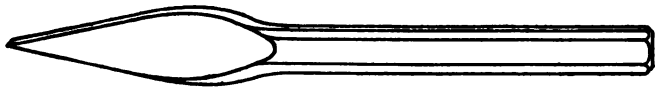


Fig. 94. Cape Chisel.

and this may best be of the quick-opening pattern, a partial turn being all that is necessary to open or close it (see Figs. 44 and 45, Part II, Heating and Ventilation).

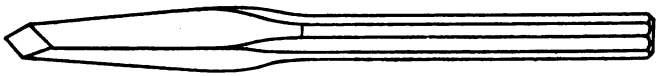


Fig. 95. Diamond-Point Chisel.

A union elbow is generally connected with the return end of a radiator (see Fig. 46, Part II, Heating and Ventilation).

Key-pattern air-valves are more frequently adopted in hot-water

Fig. 96. Round-Nose Chisel.

heating than are any types of automatic valves. They do not have to be operated often; hence the popularity of the simple and reliable air-cocks like those shown by Fig. 98.

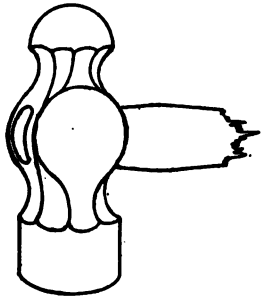


Fig. 97 *a*. Pean Hammer.

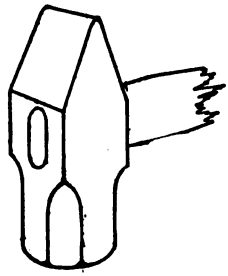


Fig. 97 *b*. Brick Hammer.

Direct-indirect hot-water radiators are seldom used, owing to the danger from freezing in case they are thoughtlessly shut off.

Indirect radiators should be of a deep pattern—say, 10 to 12 inches, or even more for use with outdoor air in a severe climate. These radiators give off far less heat per square foot than is emitted by steam radiators; hence they should be deeper, to bring the air up to proper temperature.

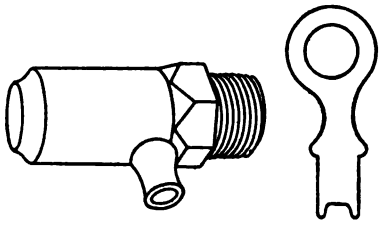


Fig. 98. Air Cock.

HOT-WATER PIPING

Heater Connections. Where only one heater is used, the connections are practically the same as for steam heating, except that no check-valves are used.

Where two boilers are to be connected and arranged to be run independently or together, valves must be inserted somewhat as shown

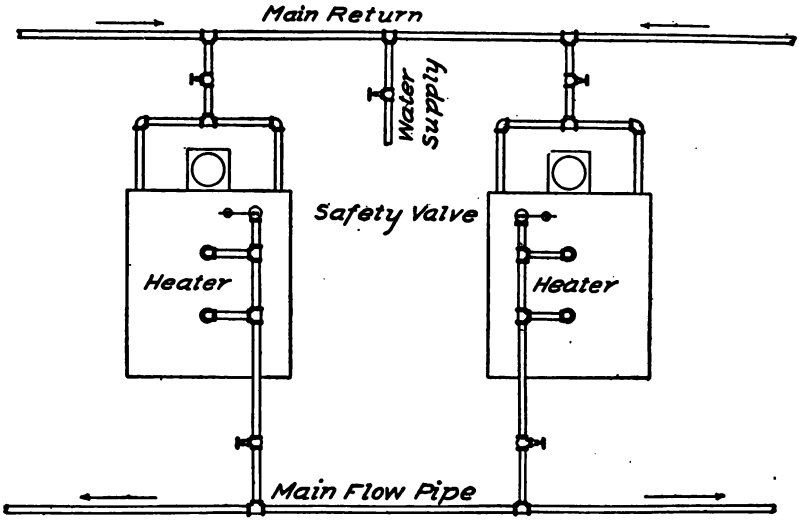


Fig. 99. Arrangement of Valves for Two Boilers which are to Run Independently or Together.

by the plan view represented in Fig. 99. It is important that safety-valves be used with this arrangement, as, in case one boiler is shut down and then fired up without opening the stop-valves, the pressure due to the expanding water will burst the heater.

Single-Main System. The single-main system, arranged some-

what like the circuit system in steam heating, is sometimes employed for hot-water heating. Fig. 100 shows the arrangement of this system. The supply branches are taken from the top of the main, where the water is hottest; and the returns are connected at the side, the cooler water passing along the lower portion of the pipe back to the heater. On systems of considerable size, this arrangement of piping causes the water in the supply main to cool more rapidly as the distance from the heater increases than in systems where the supply and return water are kept separate.

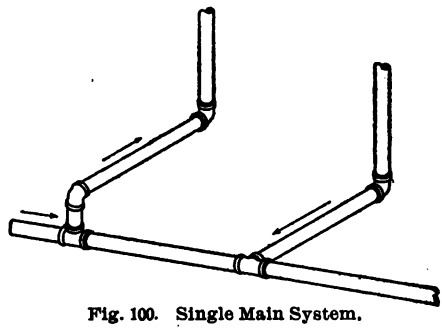


Fig. 100. Single Main System.

Two-Pipe Up-Feed System. With the two-pipe up-feed system, the pipes should be pitched up from the boiler 1 inch in 10 feet, if possible. Pockets in which air can collect must be avoided, as air will cut off the flow as much as a solid substance in the pipe would do.

In the basement, the branches near the boiler should be taken from the side of the flow main, in order to favor the branches farther

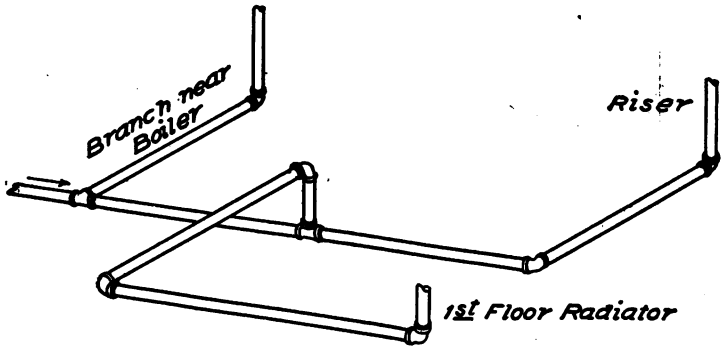


Fig. 101. Two-Pipe Up-Feed System.

away, which should be taken from the top of the main. First-floor radiators should be given the preference, as to ease of flow in their connections, over riser connections with the floors above. If possible, feed the last first-floor radiator on a line before branching to riser. Fig. 101 illustrates the above points.

Keep the mains near the ends of long runs ample in size, even if somewhat larger than stated in the table, if runs are long and crooked. No chances should be taken in regard to insuring the proper circulation of water in the system. Use no horizontal pipe smaller than 1¼-inch.

Return mains pitch in the same direction as the flow pipes, and

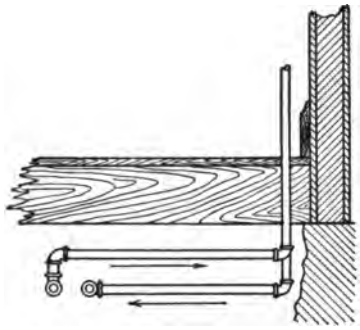


Fig. 102. Connections for Return Mains.

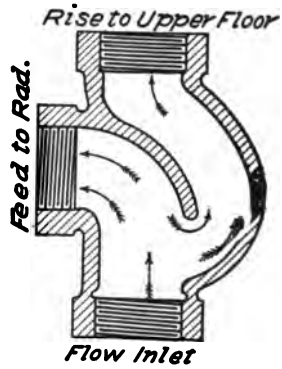


Fig. 103. Distributing Fitting.

are generally paired with them, the connections being made on the side as shown in Fig. 102, or at an angle of 45 degrees.

The risers should be arranged to favor the radiators on the lower floors, since the water tends to rise and pass by the lower radiators. Distributing fittings, as shown in Fig. 103, are often used for this purpose, or the pipes may be arranged as shown in Fig. 104. Some labor is saved by the use of the special fittings described.

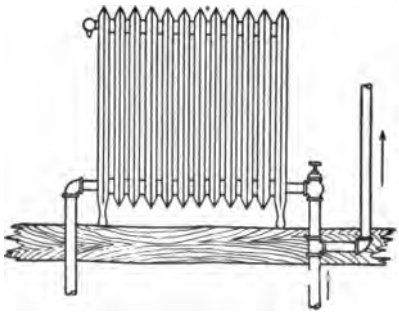


Fig. 104. Arrangement of Pipes.

Overhead-Feed System. Where attic space is available, the overhead-feed system presents certain advantages over the two-pipe up-feed method of piping. In residences, single risers are used, these serving for both supply and return, the water entering the top of the radiator and flowing back into the same riser from the lower opening in the radiator. No air-valves are necessary, all air passing up the risers and out through the vent, on the expansion tank. The overhead mains are connected with a rising main large enough to

supply all the surface; these mains may be run around the building near the walls, as in the one-pipe steam circuit system; or may be carried down the middle of the building, with long branches extending to the risers near the walls, it being assumed that the radiators will be located near the exposed parts of the building.

The mains and branches should pitch down toward the risers, permitting the air to escape freely to the expansion tank (see Fig. 105).

Special care should be used in hot-water heating, to secure an easy flow. The ends of the pipes should be reamed, and long-turn

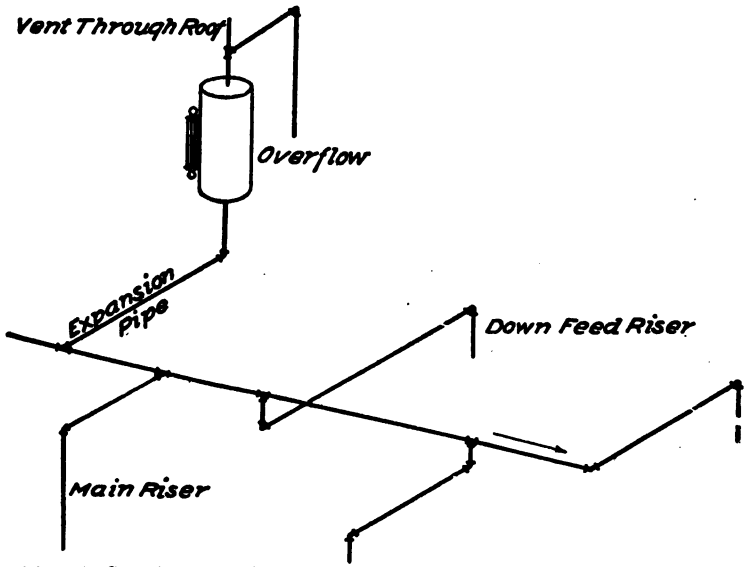


Fig. 105. Showing the Mains and Branches Pitched Down Towards the Risers.

fittings used for first-class work, although, if the piping is generously proportioned, standard fittings will answer. A hot-water thermometer should always be placed on the boiler or near it, in the flow-main.

Radiator Connections. For direct radiators, the connections are commonly 1-inch for sizes up to 40 square feet; 1¼-inch, for sizes of 72 square feet; 1½-inch to 2-inch for sizes larger than 72 square feet. On floors above the first, the connections may be made smaller if the horizontal runs are short, the sizes to conform to table.

Expansion-Tank Connections. About the simplest arrangement of expansion-tank connections is shown in Fig. 106. The expansion pipe is commonly connected with a return line in the basement, there being

less likelihood of the water boiling over in case of a hot fire with this arrangement than when the expansion pipe is merely an extension of a supply riser. There must be no valve on this pipe, as its closure would almost certainly result in a bursting of some part of the system.

Great pains must be taken to guard against the freezing of the expansion pipe. If there is any danger whatever, a circulating pipe should be added, as shown, this pipe being connected with one of the flow-pipes or supply risers, to insure a continuous circulation.

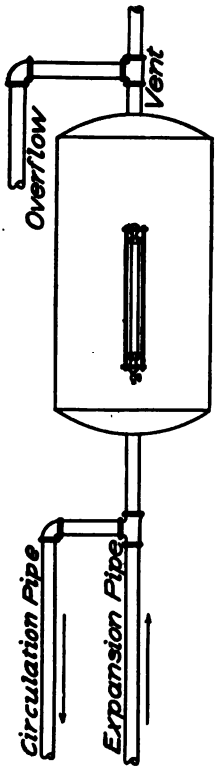


Fig. 106. Expansion Tank Connections.

Open-Tank versus Pressure System. The open-tank system, although having its disadvantages, is generally to be preferred to the pressure or closed-tank system. With the open-tank system, the water cannot get much above 212° at the heater, without boiling in the expansion tank and blowing part of the water out of the system, causing, meanwhile, objectionable noises in the system. On the other hand, the open expansion tank into which the water can freely expand when heated is the best possible safety device to prevent overpressure.

With the closed-tank system, a safety-valve is used. If it operates properly, well and good; otherwise an element of danger is introduced, and, in case an excessive pressure is developed, the heater becomes far more dangerous than a steam boiler, owing to the much greater volume of water in the system.

With this system, two safety-valves with non-corrosive seats should be used, unless some well-tested device of demonstrated merit designed especially for this purpose is adopted.

The advantage of the closed-tank system is that smaller radiators may be used, since they can be heated as hot with water under pressure as they would be if heated with steam.

When full street pressure is applied to a system, and no expansion tank is used, the radiators are subjected to an unnecessary

strain; and in case of rupture in any part of the system, much greater damage results than would be the case with an open-tank system.

System of Forced Circulation. In extensive systems the water is kept in circulation by pumps, which are capable of producing a much higher velocity in the pipes than could be secured by gravity. This system is used principally in connection with power plants, the water being heated in tubular heaters, by means of the exhaust steam from the engines. Much smaller supply mains may be used in this system than with steam heating, because of the greater capacity of water for carrying heat. On the other hand steam returns are smaller.

Table X gives the capacities of expansion tanks:

TABLE X

Radiation Capacities of Expansion Tanks

Capacity of Tank	Direct Radiating Surface to which Tank is Adapted
5 gallons	200 sq. ft.
10 "	450 " "
15 "	700 " "
20 "	1000 " "
30 "	1400 " "
40 "	1900 " "
50 "	2400 " "
60 "	2900 " "

COMPUTING RADIATION

Computing Direct Radiation. The process of computing hot-water radiating surface is precisely the same as that explained for ascertaining the amount of steam radiation required for a given case, with this important exception: the hot-water radiators give off only about $\frac{3}{5}$ as much heat per square foot as is emitted by a steam radiator; hence calculations must be based on an allowance of 150 heat units per square foot of direct radiating surface per hour, instead of 250 heat units used in connection with steam-heating work.

It has been stated that direct-indirect hot-water radiators are rarely used. In case, however, it is desired to compute the amount of this class of radiation for a given service, proceed as explained for steam heating, but allow only $\frac{3}{5}$ as much heat emitted per square foot as that given off by steam radiators.

Computing Indirect Radiation. With indirect hot-water radia-

tion in connection with the open-tank system, the radiators must be deeper than for steam heating, in order properly to heat the air.

The greater depth retards the flow of air; and since the water is at a much lower temperature than steam, the heating capacity of indirect extended-surface hot-water radiators should be taken at not far from 300 heat units per square foot per hour, as against 400 or more heat units for indirect steam radiation.

To compute the amount of radiation required, proceed as explained for indirect steam heating; that is, compute the amount of direct radiation as pointed out under the preceding heading, then add not less than 60 per cent to this amount, to ascertain the indirect radiating surface required.

This method, though perhaps crude, has the advantages of being simple and of affording a check on the work, since one soon knows by experience about what the ratio should be to heat a room of given size by direct radiation. For example, take a room with 3000 cubic feet, to heat which the ratio for direct radiation should be, say, 1 square foot to 30 cubic feet, giving a 100-square foot radiator. Adding 60 per cent for indirect radiation, gives 160 square feet, or a ratio of 1 square foot to a little less than 20 cubic feet of space.

Indirect hot-water radiators with extended pins or ribs will, with the open-tank system, give off not far from 250 to 300 heat units per hour per square foot of extended surface.

DUCTS AND FLUES

Areas of Ducts and Flues. When indirect radiation is installed primarily for heating, ventilation being a secondary consideration, it is desirable to make the flues somewhat smaller in proportion to the heating surface than is done with steam heating. If the flues are made too large, the flow through the radiators will be too rapid, and the air will not get hot enough. It costs far more in fuel to heat with a large volume of moderately warmed air than with a smaller volume of hotter air.

Duct and flue proportions for hot-water heating should be approximately as follows:—Cold-air ducts, $\frac{3}{4}$ to 1 sq. in. per sq. ft. of indirect radiating surface; first-floor flues, $1\frac{1}{4}$ to $1\frac{1}{2}$ sq. in. per sq. ft.; second-floor flues, 1 to $1\frac{1}{4}$ sq. in. per sq. ft.; third-floor flues and above, $\frac{3}{4}$ to 1 sq. in. per sq. ft. of surface.

The backs and sides of flues in exposed walls should be covered with non-conducting material.

Flue Velocities. The flue velocities will be somewhat lower than with steam heating, because of the lower temperature of the air. Reasonable allowance would be 250, 350, 400, and 450 feet per minute for the first, second, third, and fourth floors respectively.

Heating Water. The size of heater or steam coil necessary to heat water may be very readily determined on the heat-unit basis, if one knows the volume of water to be heated, the number of degrees its temperature is to be raised, and the time during which the heating must be done.

For example, what size of heater would be required to heat 300 gallons of water in 6 hours from 60° to 160°?

In one hour 50 gals. would be heated 100° F.; and since one gal. weighs $8\frac{1}{3}$ lbs., $50 \times 8\frac{1}{3} \times 100 = 41{,}667$ heat units would be required.

Small heaters may be counted on to transmit to the water about 7000 heat units per pound of coal burned. The rate of combustion should be assumed to be from 3 to 6 pounds per square foot of grate per hour, according to the amount of attendance it is convenient to give.

With a 4-pound rate, 28,000 heat units would be furnished per square foot of grate surface per hour for heating the water. Therefore the heat units per hour necessary to raise the temperature of the water—*viz.*, 41,667—divided by 28,000, gives the number of square feet of grate surface required, which is equal to about $1\frac{1}{2}$ corresponding to a diameter of $16\frac{1}{2}$ inches.

To determine the size of steam boiler and coil required to heat a large volume of water in a tank, proceed as follows: Take, for example, a 24,000-gallon tank, the water in which is to be heated from 45° to 75° in 10 hours. Now 24,000 gals. $\times$ $8\frac{1}{3}$ pounds $\times$ 30° rise in temperature = 6,000,000 heat units, or 600,000 heat units per hour.

Assuming 8000 heat units to be utilized per pound of coal burned at, say, a $7\frac{1}{2}$-pound rate, one square foot of grate will supply 60,000 heat units per hour; hence, 10 square feet of grate surface will be required.

There will, however, be a certain loss of heat from the tank by radiation, conduction, and evaporation; therefore, not less than, say, 12 square feet should be used in order to provide a reasonable margin.

As to the size of steam coil required, a square foot of pipe surface

surrounded by circulating water may be assumed to transmit to the water not far from 100 heat units per degree difference in temperature between the steam and the water in contact with the pipe.

Assume the steam temperature to be 230°, corresponding to a trifle more than 5 pounds gauge pressure. When the water in the tank is cold, the condensation of steam in the coil will be much more rapid than when the surrounding water becomes warmer. The average temperature of the water during the 10-hour period is 60°; but the water leaving the pipe and in contact with the upper half of its surface is at a considerably higher temperature than the main body of water in the tank; therefore, with natural circulation, it is well to make ample allowance for the effect of this skin of warm water surrounding the steam coils, and to assume that they will not give off more than $\frac{2}{3}$ as much heat as that corresponding to the difference in temperature between the steam and the water in the tank, based on 100 heat units per degree difference as stated above.

In other words, allow only $66\frac{2}{3}$—or, in round numbers, 70—heat units per hour per degree difference in temperature between the steam and the water in the tank.

If the difference in temperature is $230° - 70° = 160°$, on the basis stated, one square foot of coil would give off $70 \times 160 = 11{,}200$ heat units per square foot per hour; and since 600,000 heat units must be supplied to the water, a 53-square foot coil or slightly larger would be required, equal to about 122 ft. of $1\frac{1}{4}$-inch pipe.

PRINCIPLE OF HOT-WATER HEATING ILLUSTRATED BY TRANSVERSE SECTIONAL VIEW, SHOWING BOILER, RADIATOR, AND EXPANSION TANK

Courtesy of American Radiator Company, Chicago

DOMESTIC HOT-WATER SUPPLY

HEAT TRANSMISSION

Importance of Laws of Heat. Before one can sucessfully devise or install any hot-water apparatus he must make himself thoroughly conversant with the physical laws pertaining to the subject. The writer has had to answer a thousand or more queries on the causes of failure of hot-water apparatus and, although a great variety of questions would be expected, yet the failure of every plant was due to the lack of knowledge of the physical laws governing the work or of the proper proportion between the heater, boiler, etc.

Let us, then, briefly consider some of the most important properties of heat. Heat may be transmitted by three distinct methods: conduction, radiation, and convection.

Conduction. Heat is transmitted by conduction from particle to particle in a substance. If a fire is lighted under a copper heater, the heat is transmitted through the particles of metal until the interior becomes quite hot, thus heating the water. Most metals are good conductors of heat while non-metals, liquids, and gases are poor conductors. Water will not conduct heat in a downward direction and this is the reason why all circulation pipes must have a pitch in an upward direction and be free from all sags, traps, etc.

Radiation. When heat is radiated, it is given out in straight lines in every direction from some source. It does not heat the air through which it passes nor is any heat experienced until the rays impinge upon a solid body. A typical example is the radiant heat given out by the sun. We rely partially upon radiant heat to warm our buildings by means of radiators filled with hot water or steam, but in a domestic hot-water supply the circulation pipes also are throwing out radiant heat, thus wasting valuable heat and oftentimes warming some portion of the building we desire to keep cool. From this we learn that long lengths of circulation pipes

waste heat and the boiler must be placed as close to the heater as practicable. If for any reason it is not convenient to have these side by side and, therefore, long lengths of piping are unavoidable, such pipes should be covered with a nonconducting material which will prevent 90 per cent of the loss by radiant heat.

Convection. All water is heated by convection currents and if no convection and gravitation existed it would be totally impossible to obtain hot water. Convection may be described as the act of conveying heat by the ascent of heated particles. The fire is lighted under the heater and the molecules of water nearest the heater, receiving heat first, expand and become lighter than the cold and heavier water in the boiler. The heavy cold water falls by its superior weight and forces the hot and lighter molecules up to the highest part of the boiler, thus keeping up a continuous circulatory movement as long as a fire is kept going.

Expansion. The expansion of water when heated must be closely considered when devising hot-water apparatus. Water expands $\frac{1}{24}$ of its own bulk when heated from a freezing point to a boiling point, so that an apparatus containing 100 gallons of water before the fire is lighted under the heater will require provision for 104 gallons. Anything that expands becomes lighter, bulk for bulk than the original matter, and for this reason hot water always finds the highest point. Expansion of water is taking place in every system and with the tank or gravity method a pipe must be carried well above the storage tank supplying cold water to the system to allow the expansion overflow to discharge into the tank. In the street-pressure system no expansion is necessary, for as the hot water increases in bulk, it forces the cold water supply back into the street mains. A check valve should never be placed on the cold water supply, unless adequate provision can be made by providing a suitable pipe capable of holding the expanded water. If this detail is not complied with, the apparatus will give way at the weakest point.

CHARACTER OF WATER

Hard and Soft Waters. Consider, now, the character of water as supplied in various districts. All water is derived from the rainfall, and the kind of water finally obtained depends upon the

character of the ground it falls upon. Water is either soft or hard, the latter being again divided into *temporary hard* and *permanently hard.*

Soft water. If the rain, which is distilled and soft water, falls on granite, hard volcanic rocks, steep hillsides, peat, heather, moorland, or cultivated land, it remains soft and invariably has a very solvent action on iron, zinc, and lead—so much so, that the supply derived from many sources will corrode or rust a wrought heater, constructed of $\frac{3}{8}$-inch plates, completely through in a period varying from three months to three years. Besides this grave nuisance, the water is so brown in color and contains so much iron in suspension that it is unfit for even washing household utensils. Galvanizing is very little protection, for the soft water readily attacks zinc and leaves a surface of the iron exposed to the action of the water. Lead-lined tanks should never be used with soft water, for should the water become warm it acts more readily on lead, dissolves a portion, and carries it in solution. If this water be consumed by the inhabitants of the dwelling they doubtless will suffer from lead poisoning. The only satisfactory material to use in a soft water district is copper—copper heater, copper boiler, and copper pipes—while the cold-water storage tank may be constructed of copper, slate, or porcelain. Soft water has no action on these materials. Iron heaters, boilers, tanks, and pipes can be made red hot and then exposed to a current of steam for several hours. This process is supposed to render them perfectly impervious to the action of soft water. If skillfully executed, the process is satisfactory, but there is always the danger of leaving a small surface unprotected which will be attacked by the water. Again, this is rather an expensive process and makes the cost of iron almost as much as that of copper. Where the initial cost has to be considered, iron pipes lined internally with copper can be used. This form of pipe possesses the advantages of both iron and copper and is capable of withstanding a great pressure.

Hard Water. Hard waters are due to the rain falling on lime, chalk, and red sandstone. *Permanently hard waters* contain calcium sulphate and magnesium sulphate which has practically no action on any material that may be used in connection with a hot-water apparatus and any of the following materials may be used:

For heaters, cast iron, wrought iron, copper; for boilers, plain iron, galvanized iron, copper; for cold-storage tanks, plain iron, galvanized iron, copper, slate, porcelain. Of course, for a water of this description, galvanized iron is adopted most extensively on account of its lightness and cheapness. Lead pipes can be used with this water and have the advantage of being easily bent in any direction and a connection can be taken out wherever one is desired.

Temporary hard water contains the carbonates of lime and gives rise to all the trouble occurring through the furring—incrusted deposit or lime deposit—in heaters and circulation pipes. The process is as follows: The rain absorbs the carbon dioxide gas from the air as it falls from the clouds and also as it percolates into the ground (the ground contains 250 times more of this gas than the air above it). This water charged with carbon dioxide dissolves a small quantity of lime and carries it in solution. On reaching the heater, the heat from the fire causes the water to become very hot at times, and this water being under pressure often attains a temperature of 300° F. When the water reaches these high temperatures the carbon dioxide is driven off, thus immediately liberating the lime and precipitating it on the sides and bottom of the heater and in the circulation pipes. It must be remembered that a considerable quantity of fresh water has to pass through the heater each day and each heater full of water deposits a quantity of lime. The exact quantity depends on the hardness of the water and the temperature it reaches in the heater. No lime is precipitated unless a temperature of 212° F. is reached. This deposit must be cleaned out at regular intervals by removing the circulation pipes and heating and hammering them on a solid body until all the deposit is shaken out. The contents of the heater may be chipped out with a hammer and chisel. In all cases the circulation pipes should be at least 1¼ inches in diameter, then it will take longer for them to stop up; when stoppage actually occurs, the lime will be more readily removed than in the case of a 1-inch or ¾-inch pipe. If the deposit is allowed to accumulate, the heater and pipes become partly choked and give rise to a very disagreeable noise. Moreover, a little hot water can be obtained, for the lime, being a bad conductor of heat, prevents the

heat passing through to the water. The heater is also liable to be fractured, for the lime prevents the water from coming into contact with the surface of the heater. One often hears the expression: "Copper heaters and circulation pipes should be used in temporary hard water districts, for the lime deposit will not adhere to copper". Now this opinion is incorrect, for it has already been shown that water causes the trouble and not the material. Moreover, if copper is used, being of a soft nature, it is more likely to be damaged with the hammer and chisel than iron. On no account should lead pipes be used, as the incrusted deposit cannot be removed and consequently the pipes will have to be thrown on the scrap heap. Any material can be used for boilers, tanks, and supply pipes, for the water in the boiler rarely becomes hot enough to liberate the lime. Furthermore, if such a temperature is reached all the lime in the water is sure to be liberated in the heater.

HEATERS AND BOILERS

Size of Heater. The heater itself must receive special attention. As already mentioned all hot water is derived from the heater and, if we wish to obtain successful results, we must use discretion in selecting an efficient type for the varying conditions under which they may operate. One type may give excellent results with one particular heating system yet prove totally unfit for another. The capacity of the heater is regulated by the demand for hot water in any building. Many persons are under the impression that the smaller the heater the quicker the circulation; consequently, an abundant quantity of hot water will be obtainable in a short time. Others argue that the heater should be as large as possible, for all the water comes from it. Now, in the first instance, let us assume that we have a heater of 1-gallon capacity and a 250-gallon storage capacity for the hot water in the storage tank, known as the boiler. The circulation under these conditions will be quick, but such a small volume of water passes into the boiler that it will be very late in the day before an appreciable quantity of really hot water can be drawn from the faucets. Coming now to the second argument, that is, a large heater, an apparatus which recently came under the writers' notice consisted

of a 48-gallon heater while the boiler contained only 30 gallons. This apparatus is quite as bad as the first for no ordinary range has sufficient fire area to heat such a volume of water, and an independent type would be necessary which, in this case, would keep the 30 gallons boiling all the time. The required grate surface of the heater may be computed as follows: First determine or assume the number of gallons to be heated per hour and the required rise in temperature. Reduce gallons to pounds by multiplying by 8.3, and multiply the result by the rise in temperature to obtain the number of thermal units. Assuming a combustion of five pounds of coal per square foot of grate and an efficiency of 8000 thermal units per pound of coal, we have the formula

$$\text{grate surface in sq. ft.} = \frac{\text{gallons per hour} \times 8.3 \times \text{rise in temperature}}{5 \times 8000}$$

Example. How many square feet of grate surface will be required to raise the temperature of 200 gallons of water per hour from 40 degrees to 180 degrees? Substituting values in the above formula, we have

$$\text{grate area} = \frac{200 \times 8.3 \times (180 - 40)}{5 \times 8000} = 5.8 \text{ square feet}$$

In computing the amount of water required for bathtubs, it is customary to allow from 20 to 30 gallons per tub, and to consider that the tub may be used three or four times per hour as a maximum during the morning. This will vary a good deal, depending upon the character of the building. The above figures are based on the apartment hotel practice. For all buildings other than cottages, the independent heater is preferable to the range water back, but many think otherwise. The popular arguments against its use are as follows: A fire has to be kept going in the kitchen range for cooking purposes, etc., and a water back might just as well utilize the waste heat; moreover, the independent type takes up time attending to it and it burns a quantity of fuel.

Now it is true that the water back does utilize a small quantity of heat, but it is very extravagant and takes up nearly all the heat from the fire. The cold heater deadens the fire and requires a quicker draft to keep it sufficiently bright than when fire bricks exist instead of the heater. Thus, without the heater

the range would require less attention, less fuel, and work much better. The independent heater will burn coke, cinders, or any household garbage, thus acting as a small incinerator. It requires only five minutes attention twice a day and will supply an abundant quantity of really hot water any time, day or night. Hot baths can be had without the least inconvenience before breakfast, which is beyond the capabilities of most range heaters. In temporary hard-water districts, the heater can be cleansed without interfering with the cooking processes. It stands complete in itself and can be put down in any position, while the chimney can be independent or connected with any existing flue. In hard-water districts, the heater should be provided with a waterway bottom, into which the lime falls in the form of a sludge and remains in this state until removed from the mudhole provided at the bottom.

Boilers. It is essential in most systems to provide some means of storing the hot water, for the heater is of small capacity and, therefore, the hot water is quickly exhausted. A boiler properly proportioned to the size and power of the heater and amply large enough to meet the demands for hot water at the busiest time of the day is imperative to store the hot water derived from the heater. The material used has already been described, but whatever the material, it must be capable of withstanding a pressure of 40 pounds per square inch and should in every instance be tested before leaving the works. As a general rule, the boiler is sent out with two openings for the pipe connections on the top, two on the side and one at the bottom, but these can be placed in any desired position if specially ordered.

SYSTEMS OF SUPPLY

Street Pressure System. A street pressure system suitable for the ordinary type of small residence is shown in Fig. 1. A pipe is taken direct from the street pressure supply and connected with the top of the boiler. A tube is carried down to within 6 inches of the bottom to prevent the cold water from discharging and splashing into the hot water which, naturally, is at the top of the boiler. The tube should have a $\frac{1}{8}$-inch hole drilled in about 1 inch from the top of the boiler so that air will enter and break

the siphon and thus avoid inadvertently emptying the boiler when intending only to cut off the supply and drain the pipe. The siphon-hole, as it is termed, should be turned in the direction opposite the eccentric hole, which is for the hot-water exit, so that the stream of cold water which issues there when water is coming into the reservoir will not cut across and interfere with the hot service which is always leaving the boiler at the same time. If the delivery were placed nearest the side hole, hot water from the stove would have to pass around it in order to reach the exit.

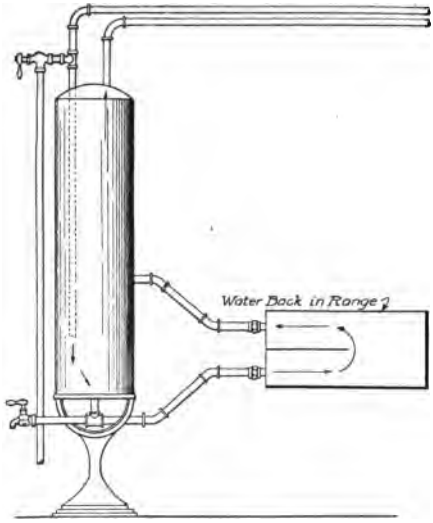


Fig. 1. Diagram of Street Pressure Water System for Small Residence

Delivering the cold water through a pipe passing down through the volume of hot water is no material retardation of the heating process. The heat thus absorbed by the cold delivery is simply that much aid to the ultimate purpose. This cannot be said of the siphon-hole jet when directed across the hot exit or in its direction. The object in putting the siphon-hole near the upper head is to avoid siphoning more water than necessary, as the waste tubes of the stop and waste cocks are generally left open, not connected to drains, and often not even discharging where the waste can be left to take care of itself. Moreover, it is a waste of the stored hot water to siphon out several inches from the hottest point. The cold water now passes into the heater through the pipe provided at the bottom of the boiler, receives heat, convection currents are set up, and the hot water circulates back into the boiler through the hot flow pipe furnished about 18 inches from the bottom of it. Care should be taken not to have the hot flow pipe connected below the extreme top of the heater, otherwise an air space or air pocket which cannot be filled with water will be formed, thus causing the formation of steam

with accompanying noises, even if no other consequence presents itself.

A pipe is taken directly off the top of the boiler and is carried to the various points at which a supply of water is desired. The street pressure brought to bear on the contents of the boiler forces the water to the desired height and, assuming the fire is kept going and the aforementioned details are complied with, hot water will be obtainable on the opening of a faucet. A sediment cock should be provided on the cold supply to the boiler, so that the entire contents of the system can be emptied in the case of repairs, etc. Further, all sediment occurring in the boiler can be removed periodically through this cock. It is very convenient to fix a shut-off cock on the cold supply close to the boiler. This cock when closed shuts off the whole of the hot water supply, yet it does not interfere with the cold-water supply throughout the building.

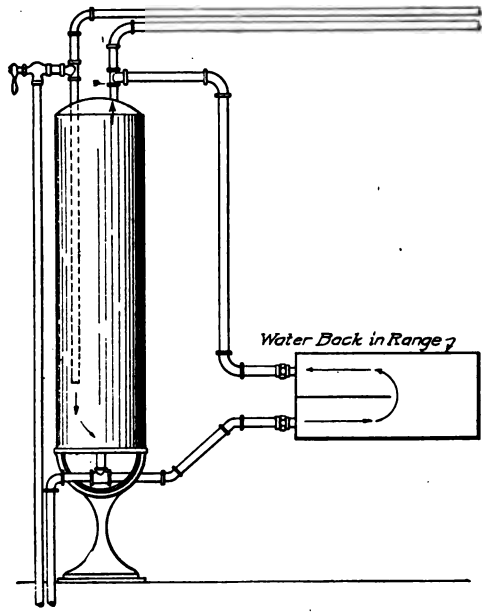


Fig. 2. Modification of System Shown in Fig. 1, Giving Quicker Results

Where quick results are desired, the flow pipe is not taken to the boiler as shown in the former method but connects with the hot supply some 6 inches above the top of the boiler as shown in Fig. 2.

Disadvantages of System. Theoretically, the system is ideal, for it is not necessary to heat the entire contents of the boiler before hot water is obtainable. As soon as the fire is lighted the hot water circulates direct into the supply pipe and can be drawn from the faucet without delay. However, in practice the results are not all that could be desired. It must be remembered that as soon as a faucet is opened, all circulation ceases and the water

flows from every direction to the point of issue. Thus, the cold water rushes through the heater direct to the faucet, and the fire under the heater is not capable of raising the water to a satisfactory temperature in such a brief space of time. It is serviceable when about one gallon of water is required.

Secondary Circulation System. The connection for a secondary circulation is shown in Fig. 3. If the building is such that it necessitates long straggling branches, the hot-water supply pipe must be carried from the top of the boiler, with a pitch of at least $\frac{1}{4}$ inch to one foot, to the remotest branch, thence returning to the cold supply to the heater with a continuous fall. It must be clearly understood that there is no circulation in a single pipe and, if long branches are in vogue, the whole contents of the branch pipes will have to be run off before hot water is forthcoming. Just as soon as the faucet is closed the hot water contained in the branch pipe becomes stagnant and cold. To obviate this the circulation pipe, or secondary flow and return, as already described, is adopted, which allows the water to circulate continuously throughout the entire system. The branches to the fixtures which must be as short as possible, can be taken from the flow, that is, the pipe rising to the highest point, or the return, the pipe returning to the cold supply to the boiler. Sometimes provision is made in the boiler for the connection, 4 to 8 inches from the top. This is really the correct position and will give the most satisfactory results; manufacturers do not, as a rule, provide this connection on their stock boilers.

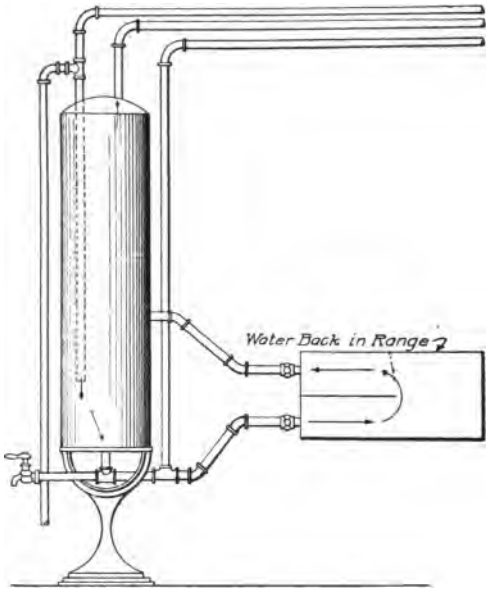


Fig. 3. Diagram of Hot-Water System with Secondary Circulation

Gravity Supply System. A typical arrangement of the gravity supply system is shown in Fig. 4. This method of domestic hot-water supply constitutes an entirely different arrangement of supply, services, etc., to those previously mentioned. The outflow of hot water through the faucets depends on the pressure derived from the cold-water storage tank which, naturally, must be fixed in an elevated position above all the fixtures to be supplied. This tank is supplied with water direct from the street main, if the height of same renders such a procedure practicable, or in case of high buildings where the street pressure is not capable of raising the water to the desired height, a pump, water lift, or other mechanical device is employed. The tank must be provided with an overflow pipe sufficiently large to carry off any surplus water and discharge with an open end into an open water-supplied sink or into a deep-sealed trap. The boiler, the heater, and cold supplies to the faucets are supplied direct from this tank, and to take care of the expanded water an expansion pipe is taken off the highest point of the apparatus, carried up two feet above the top of the tank, and discharges with an open end into the latter. Branches are taken out of the hot-supply pipe and, if so desired, a secondary circulation may be used in connection with the system. It is absolutely imperative to adopt this method in those districts having an indirect water supply, where the water is only turned into the mains a few hours daily, also in high buildings as the street pressure in most localities will not raise the water to a greater height than five stories.

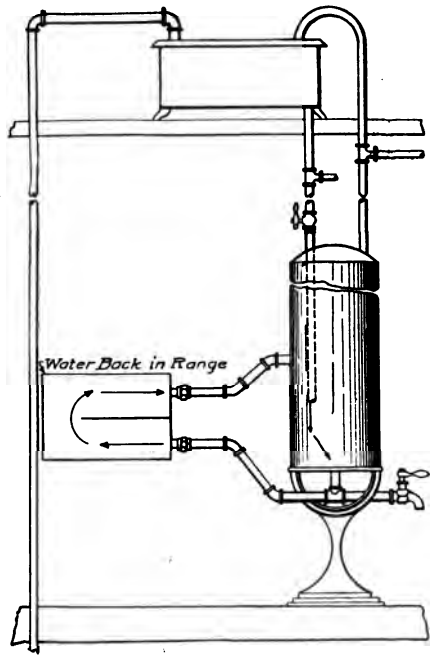


Fig. 4. Diagram of Gravity-Supply Hot-Water System

Double-Boiler System. *Method A.* The double boiler, Fig. 5, is adopted when the pressure of the water in the street mains will not supply the upper floors of the building with water and it is not desired to supply the entire building from a tank. The lower floors of the building are supplied with the street pressure supply and the upper ones from a tank on the gravity system. One heater in the range, or preferably an independent heater, heats the water of both supplies by means of a double boiler. This consists

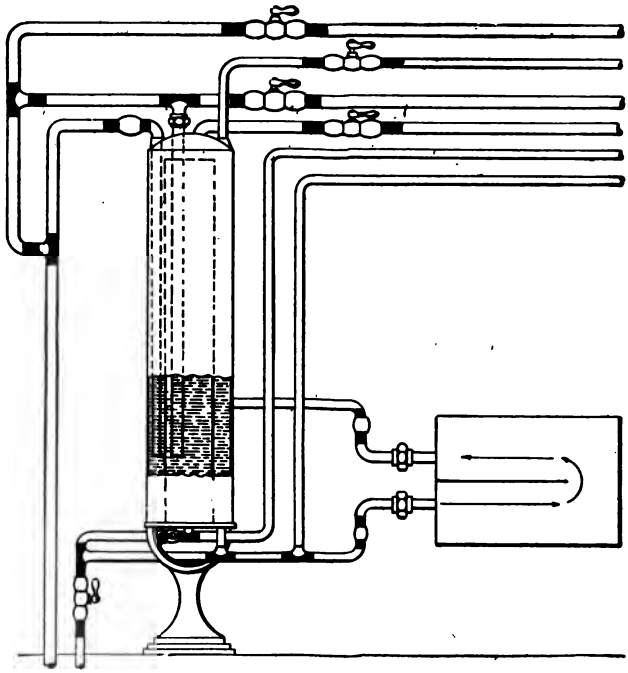


Fig. 5. Diagram of Double-Boiler System of Hot Water, Both Street Pressure and Gravity Tank Being Used

of a boiler within a boiler. The inner boiler contains the water from the tank and is known as the *high-pressure* boiler, while the other is supplied direct from the street pressure and is termed the *low-pressure* boiler. The water in the outer boiler is connected to the heater and the water in the inner boiler is heated by conduction through the boiler shell. A by-pass is provided between the two cold supplies to the boilers and controlled by a check valve. The draw-off cocks of the boilers are arranged in such a manner

that the water in the inner boiler cannot be drawn off without emptying the outer boiler at the same time, so that in the event of failure from the tank supply, the street pressure supply would keep the inner boiler supplied through the check valve and prevent it from collapsing. If the water be drawn from the inner boiler and the outer boiler is kept full, the excess pressure of the outer boiler would collapse the inner one. It may be mentioned here that the double-boiler practice is rapidly losing favor owing to its general inefficiency. The inner boiler being heated by conduction, it is imperative to use copper plates of light weight in its construction, and these invariably give way under the expansion, contraction, and pressure of the water, causing the water from the two to intermingle and make one boiler instead of two.

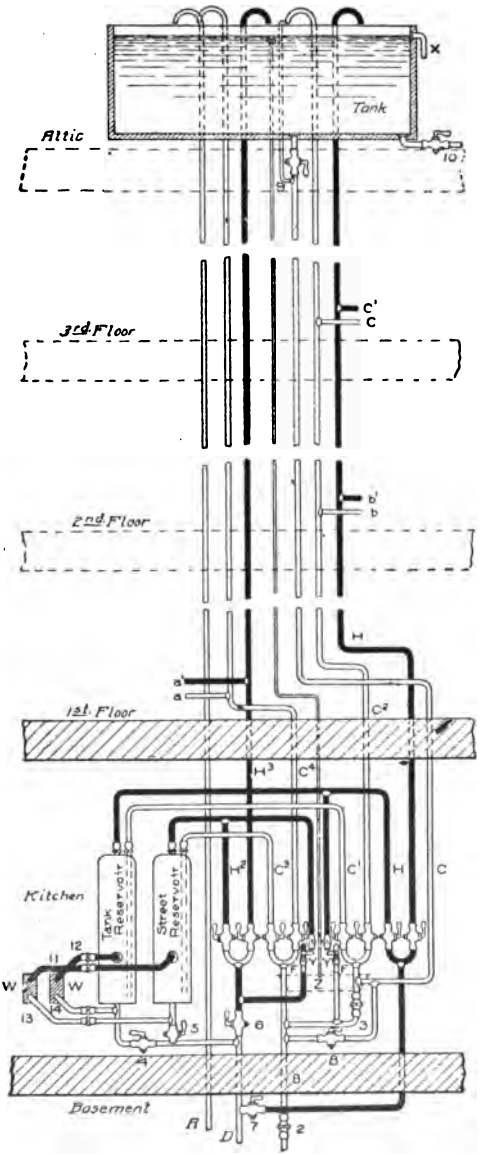


Fig. 6. Layout for Another Double-Boiler System

Method B. Another method of providing double-boiler service is shown in Fig. 6. *A* is a $1\frac{1}{4}$-inch pipe leading directly to the tank and bending over the top. It is connected to a pump

in the basement. *B* is the main supply from the street to which pipe *A* is connected at a lower point; *2* is a check valve placed in the main street supply for the purpose of preventing the pump from drawing water from the street pressure boiler while pumping water into the tank in the attic. This might occur for various reasons if a check valve is not used, and would certainly result in case the pump should be operated while the street supply was shut off. Check valve *2* also prevents the tank water from going into the street pipe when both systems are working at high pressure. In practice, a drain cock should be placed in pipe *B* above check valve *2*. *C* is the main cold supply leading directly from the tank to the kitchen without branches to fixtures at any point. It connects above check valve *3* to a pipe leading to the tank pressure reservoir. From the lower end of check valve *3*, a pipe leads over to the main cold supply *B*. The superior pressure of the tank system keeps check valve *3* closed, so that water cannot enter the tank system or reservoir from the street while there is pressure upon it from the tank supply. However, immediately upon the tank becoming empty, or its pressure shut off at cock *9*, the pressure falls in the tank system pipes until the pressure is inferior to the street pressure, and check valve *3* opens upward and allows the street pressure to keep the tank pressure reservoir filled. Otherwise, trouble might possibly result, but it is not so probable as in jobs having one boiler within the other. This check admits of both boilers filling without having water in the tank when the job is first started; and, although it is a minor point to mention, it is best to be prepared for accidents.

The main cold supply from the tank is controlled by stop cock *9*. Just below the cock a small pipe is branched in, carried up, and curved over the top of the tank so as to admit air when it is desired to drain the pipe. *D* acts as a drain to the hot water pipes of both boilers. The sediment pipes of the boilers are also connected to it.

To aid the reader in tracing the different pipes easily, all the hot-water pipes are represented by heavy black lines and the cold water pipes by double parallel lines. *C'* is the cold supply to the tank pressure reservoir; C^2, tank supply, cold water, to fixtures on second and third floors; C^3, cold supply to the street pressure

reservoir; and C^4, cold supply from the street pressure to the fixtures on the first floor. *FF* are the hot and cold-water faucets at the kitchen sink, the hot being on the left side. *H* is the main hot supply of the tank system; *H'* is the hot supply from the tank reservoir to the fixtures on the second and third floors; and H^2 is the main hot supply from the street pressure reservoir to the fixtures on the first floor. It will be noticed that each of the supplies has been carried up as high as the top of the tank and curved at the end so that they will discharge into it, which, in the case of hot supplies, might occur from steaming. The extension of the fixture supplies to the top of the tank, with the ends left open, insures that they will drain themselves when the water is shut off; and also cushions the pressure when the faucets are turned off quickly, the same as the air chambers do on direct-pressure systems.

The hot and cold supplies from the street reservoir might be left off at any point where the branches are made on the first floor, without causing any material difference in the working. In that case, however, there would be no vapor relief for the reservoir through the hot-water pipe; and when the cocks were shut off, none of the pipe would drain unless the faucets were opened upstairs. As it is, the main line will drain whether the faucets are open or not; and there is also the advantage of the air cushion and relief as well.

Of the cocks over the kitchen sink, only those which have waste tubes indicated on the pipes leading to the fixtures on the upper floors, are stop and waste cocks. The others are plain stops which prevent any chance of causing them to waste continually by some error in using them. Stops and wastes would be of little value on the lines above the sink which lead direct to the boilers, because it is not particularly desirable to drain any of the pipe between the cocks and the reservoirs while the cocks mentioned are shut off.

The branches *aa'*, *bb'*, and *cc'* are of $\frac{5}{8}$-inch pipe and supply pipe and supply fixtures on the first floor from the street pressure and on the second and third floors from the tank pressure. *WW* represent water backs, both of which are in the same range of firebox. One water back is connected to the tank reservoir by

means of circulating pipes *12* and *14*, while the other is connected to the street reservoir by pipes *11* and *13*. The sediment pipes of the reservoirs are controlled by cocks *4* and *5*. Both of the sediment pipes discharge into the general drain pipe *D*. The overflow pipe of the tank is indicated by *X*. *Y Y* are vacuum valves situated over the kitchen sink. They communicate with the reservoirs through branches from the main hot supplies.

By referring to the engraving the reader will see that there is no way to cut off communication between the reservoirs and the vacuum valves. With the valves placed at the sink as shown, the weight of the water in the vertical pipe above the valves must be overcome before air will enter the reservoirs. If desired, the valves may be placed in the heads of the reservoirs, and a pipe carried over to the sink to take care of the drippings. In this style of double-boiler work, vacuum valves are not so important as they are in systems having one reservoir within the other, because the boilers here described work under about the same conditions as those in ordinary single-boiler jobs. The telltale pipe *Z* discharges over the kitchen sink. Cock *6* drains the hot-water pipe from the street reservoir and cock *7* drains the hot-water pipe from the tank reservoir.

Cock *8* is placed in a connection where, when turned on, it allows the tank pressure to by-pass check valve *3*. By this means both systems may be worked under high-pressure duty when the street pressure is shut off. In a case where the street pressure is constant for the fixtures on the first floor, but does not reach the second, cock *8* will seldom have to be used, and it should then be of a type having a removable handle.

One point gained by bringing the pipes down and up, as shown by the loops over the sink, is that every stop can be reached from the floor without the aid of a ladder. The fixtures on the upper floors can be shut off without interfering with the supply to the kitchen sink or other fixtures that may happen to be on the lower floors.

The sizes of the pipes shown in this installation, which have not already been given, are as follows: *B* and *C*, $\frac{3}{4}$ inch; *C'*, *C*^{2}, *C*^{3}, and *C*^{4}, $\frac{5}{8}$ inch; *D*, $\frac{3}{4}$ inch; *FF*, $\frac{5}{8}$ inch; *H*, *H'*, *H*^{2}, and *H*^{3}, $\frac{5}{8}$ inch; *X*, $1\frac{1}{2}$ inch; *YY*, $\frac{1}{2}$ inch; Z, $\frac{3}{8}$ inch; *11* and *12*, 1 inch;

and *13* and *14*, ¾ inch. Cocks *4* and *5* are ¾ inch; *6*, *7*, and *8*, ⅝ inch; and *10*, 1¼ inch.

Horizontal Boilers. A horizontal boiler connected to an independent gas heater is shown in Fig. 7. Where space is limited, such as in the basement of a building, it is often difficult to install a vertical boiler of adequate size to store the necessary amount of hot water. However, this difficulty is easily overcome by suspend-

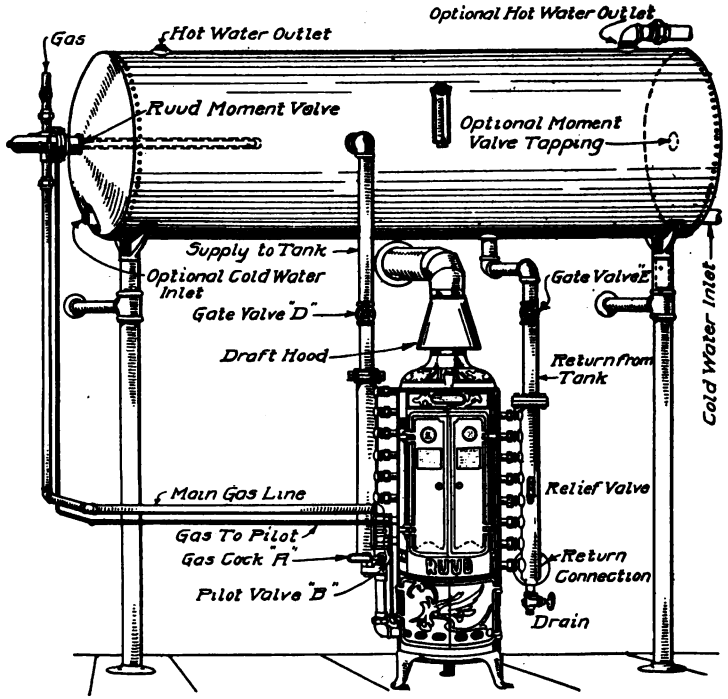


Fig. 7. Complete Layout for Hot-Water Storage System, Using Ruud Automatic Gas Heater

ing the boiler by means of strong iron hangers from the basement ceiling in a horizontal position and immediately over the heater. The connections are very similar to those adopted in the other system. The supply may be direct from the street or, in the case of high buildings, from the tank in the attic. The boiler tube with the siphon-hole is carried down to within 3 inches from the bottom of the boiler and the cold water flows through the cold

supply to the heater fixed in the bottom or in the side 3 or 4 inches from the bottom. The hot circulation pipe is connected in one end and about the center of the boiler, while the hot supply

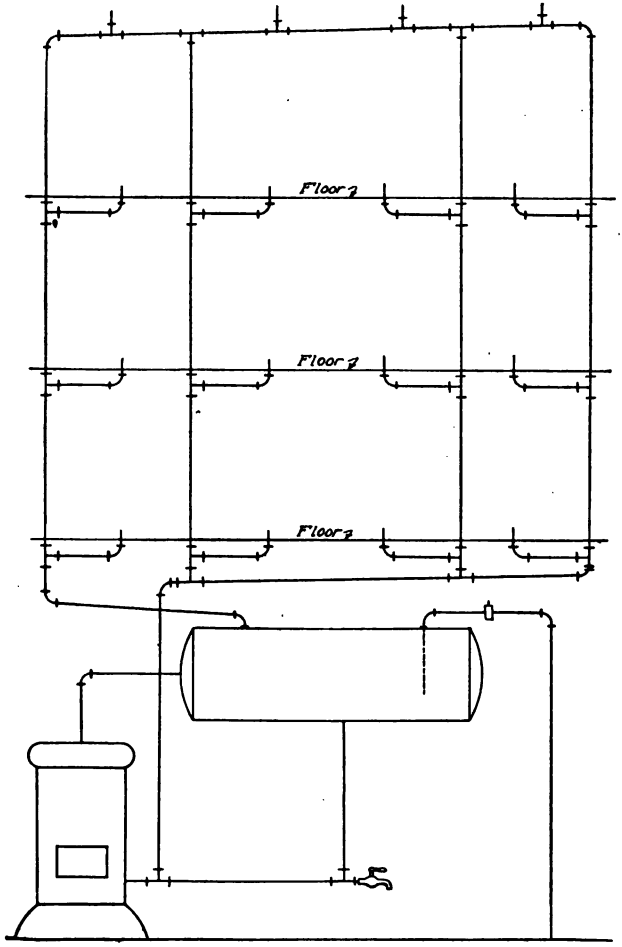


Fig. 8. Layout of Hot-Water System with Horizontal Boiler for Large Building

is taken off the extreme top and supplies the fixtures. An emptying pipe with sediment cock must be provided for emptying and cleansing purposes.

Another horizontal boiler arrangement suitable for a fairly large building is shown in Fig. 8. The horizontal boiler is supplied

direct from the street pressure and the hot water is derived from an efficient independent heater. The secondary circulation pipes rise to the highest point, thence returning to the cold supply to the heater. It will be noticed that branches are taken from both the flow and return pipes.

The ordinary vertical boiler may be used as a horizontal boiler without making any alteration. Most vertical boilers have two openings on the top—one for the hot supply to the fixtures and the other for the cold supply to the boiler. When this boiler is fixed in a horizontal position with the side connection facing the ceiling, both the flow and the return from the heater

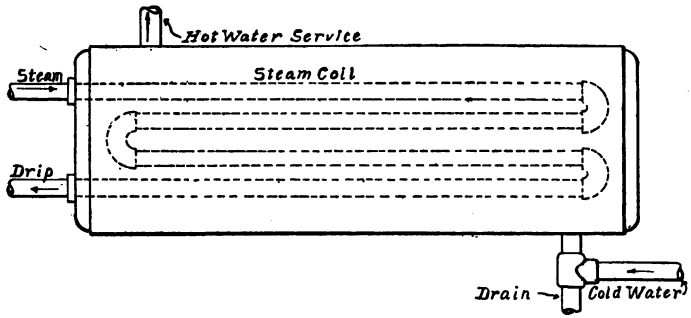


Fig. 9. Horizontal Hot-Water Storage Reservoir with Steam Coil of Brass Pipe for Heating Used Where Steam Pressure Is Constantly Maintained

are connected with these openings. The cold supply is connected with what would ordinarily be the return to the heater, a 45-degree ell and a short piece of pipe being attached in order to convey the cold water to the bottom of the boiler. The flow pipe from the heater is connected with the hot supply about 4 inches from the top of the boiler, while the return to the heater is taken from the center of the boiler and usually forms the hot supply to the fixtures. A 45-degree ell and a short piece of pipe are carried to within 2 inches of the bottom of the boiler.

Steam Coils. In apartment or other houses where steam pressure is constantly maintained, the whole plumbing system is usually supplied with hot water through the medium of a reservoir provided with a steam coil of iron, brass, or copper pipe, as shown in Figs. 9 and 10. The *trombone*

coil, illustrated in Fig. 9, can be used only on horizontal tanks; it would not drain in any other position. The condensed steam is wasted into the sewer, delivered to a hot well, or returned by steam trap.

The efficiency of a steam coil when surrounded by water is much greater than when placed in the air. An iron pipe will give off about 200 thermal units per square foot of surface per hour for each degree difference in temperature between the steam and the surrounding water. This is assuming that the water is circulating through the heater so that it moves over the coil at a moderate velocity. The condensing power of galvanized pipe is very nearly the same as that of plain iron, its coating being an alloy and not pure zinc as is generally supposed. The ratio of absorption decreases as the temperature of the water approaches that of the steam surface. In assuming the temperature of the water, take the average between that at the inlet and that at the outlet.

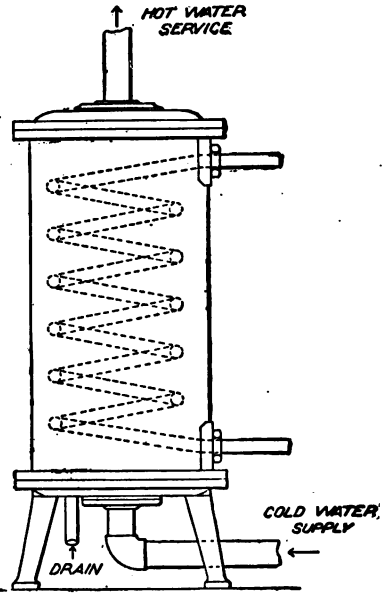


Fig. 10. Vertical Storage Reservoir with Steam Coil of Iron, Brass, or Copper Pipe for Heating, Used Where Steam Pressure is Constantly Maintained.

Example. Find the heating surface required in an iron coil to heat 100 gallons of water per hour from 38 degrees to 190 degrees, with steam at 5 pounds' pressure?

Water to be heated = $100 \times 8.3 = 830$ pounds.

Rise in temperature = $190 - 38 = 152$ degrees.

Average temperature of water in contact with the coils

$$= \frac{190 + 38}{2} = 114 \text{ degrees.}$$

Temperature of steam at 5 pounds' pressure = 228° approximately (actually 227.964°).

The required B. T. U. per hour $= 830 \times 152 = 126{,}160$.

Difference between the average temperature of the water and the temperature of the steam = 228 − 114 = 114 degrees.

B. T. U. given up to the water per square foot of surface per hour = $114 \times 200 = 22{,}800$. Therefore,

Number of feet of heating surface required = $126{,}160 \div 22{,}800 = 5.5$ square feet of surface or 12.6 lineal feet of 1¼-inch, or 16 lineal feet of 1-inch pipe.

EXAMPLES FOR PRACTICE

1. How many linear feet of 1-inch iron pipe will be required to heat 150 gallons of water per hour from 40 to 200 degrees, with steam at 20 pounds' pressure? Ans. 21.3 feet.

2. How many square feet of grate surface will be required in a heater to heat 300 gallons of water per hour from 50 to 170 degrees? Ans. 7.4 sq. ft.

3. A hot-water storage tank has a steam coil consisting of 30 linear feet of 1-inch iron pipe. It is desired to connect a coal-burning heater for summer use, which shall have the same capacity. Steam

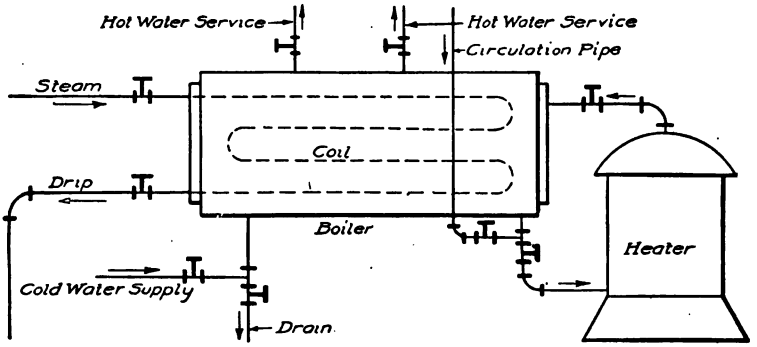


Fig. 11. Storage Tank Heated by Steam Coil in Winter; Cross-Connected to Coal Heater in Summer.

at 5 pounds' pressure is used, and the water is raised from 40 to 180 degrees. How many square feet of grate surface are required? Ans. 5.9 sq. ft.

4. A hotel has 30 bathtubs, which are used three times apiece between the hours of seven and nine in the morning. The hot-water system has a storage tank of 400 gallons. Allowing 20 gallons per bath, and starting with the tank full of hot water, how many square feet of grate surface will be required to heat the additional quantity of water within the stated time, if the tempearture is raised from 50 to 130 degrees? Ans. 11.6 sq. ft.

If steam at 10 pounds' pressure is used instead of the heater, how many square feet of heating coil will be required? Ans. 15.3 sq. ft.

Calculating Coil Surface. Heat transmission from steam to water in iron pipe increases with temperature difference from 150 B.t.u.

per square foot, per hour per degree for 100° difference, to 228 B.T.U. for 125° difference. The relative condensing power of submerged iron, brass, and copper pipe is about as 2, 4, and 5, respectively. Within the range of water temperatures usual in practice and with steam at ordinary pressure, we may safely place the condensing power of iron, brass, and copper pipe in even tenths, .2, .4, and .5 pounds per hour, per square foot, per degree difference between the steam and mean temperature of the water. With these values, the latent heat of steam, say 960, should be used in converting heat units, found as in preceding examples, into "pounds" of steam. Having this latter, the process of finding the coil surface would be: multiply the temperature difference by the constant .2, .4, or .5, according to the kind of pipe coil to be used, and divide the "pounds" of steam by the product so obtained. The result will be coil surface in square feet, which may be converted into lineal feet by multiplying by 2.9 for 1-inch pipe; by 2.3 for 1¼-inch pipe; by 2.0 for 1½-inch pipe, and by 1.6 for 2-inch pipe. As in some of the previous examples three feet of 1-inch pipe are generally taken as one square foot. Sometimes a storage tank

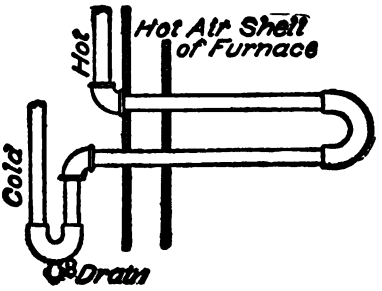


Fig. 12. Cross-Connection of Storage Tank to Firepot of Furnace

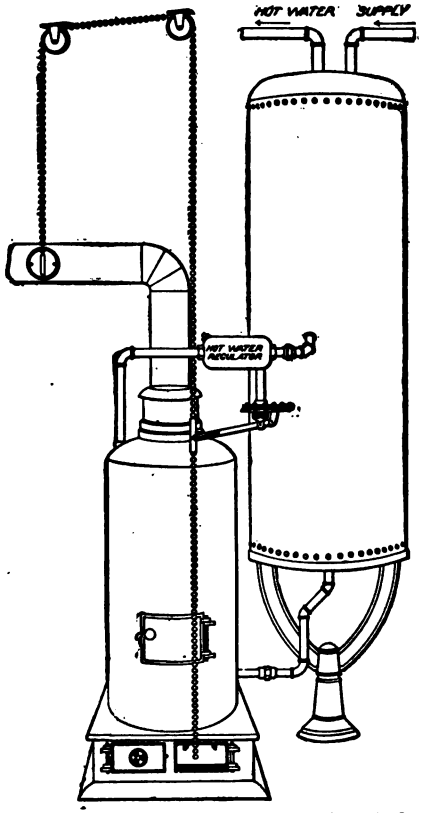


Fig. 13. Temperature Regulator Attached to Coal Heater.

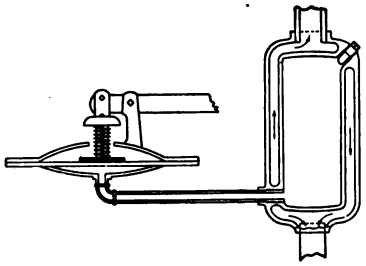


Fig. 14. Steam Generator of Temperature Regulator Shown in Fig. 13

is connected with a steam-heating system for winter use, and cross-connected with a coal-burning heater for summer use when steam is not available. Such an arrangement is shown in Fig. 11. A cross-connection for the same purpose is often made to the fire-pot of the house-warming heater,

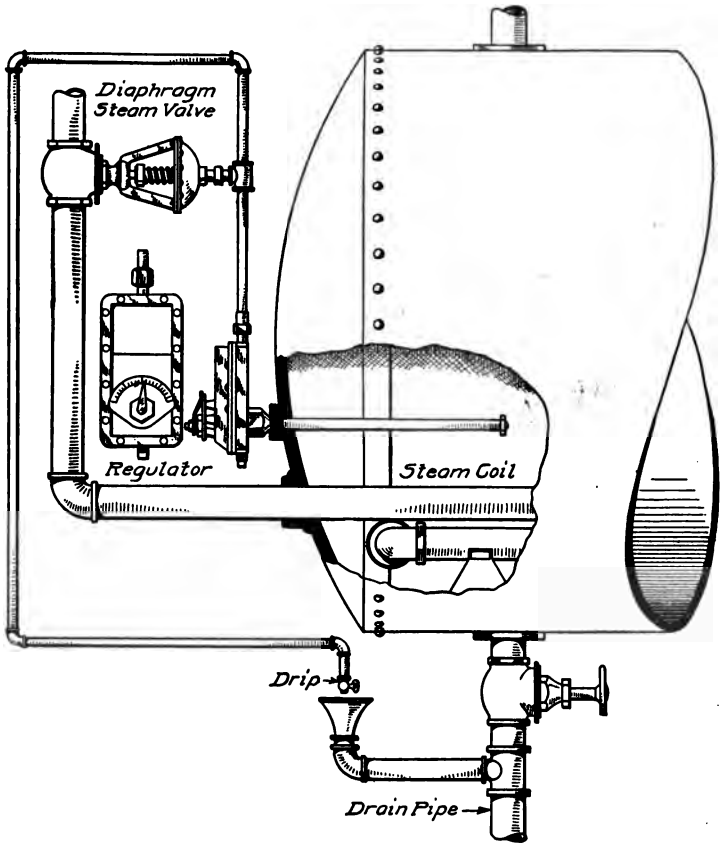


Fig. 15. Temperature Regulator Connected to Steam Coil

as indicated in Fig. 12. A drain at the lowest point is essential, but a dip as deep as the one shown is not necessary.

Temperature Regulation. Hot-water storage tanks having special heaters or steam coils should be provided with some means for regulating the water temperature. Figs. 13 and 14 show a simple form attached to a coal-burning heater. An outer shell is connected with the circulation pipe as shown in Fig. 13. An inner chamber connects with a space below a flexible rubber diaphragm in a separate case adapted to operate the draft lever.

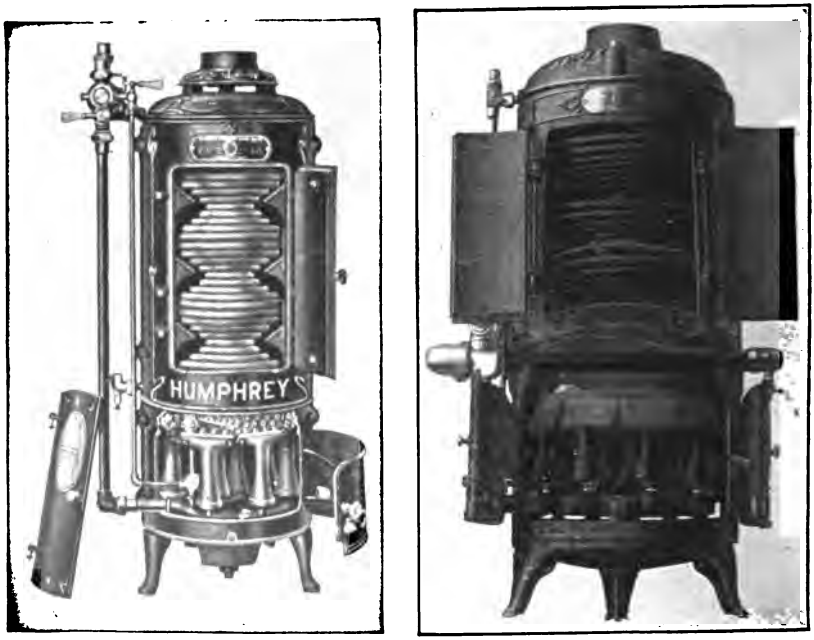


Fig. 16. Typical Automatic Gas Heaters for Instantaneous Hot-Water Service
Left—Humphrey Heater; Right—Ruud Heater.

A form of regulator for use with a steam coil is shown in Fig. 15. This consists of a rod made up of two metals having different coefficients of expansion, and so arranged that the difference in expansion will produce sufficient movement to open a small valve when the water reaches a given temperature. This allows water pressure from the street main with which it is connected, to flow into a chamber above a rubber diaphragm, thus closing the steam supply to the coil. When the water cools, the rod contracts, and the pressure is released above the diaphragm, the valve opening to admit steam again.

Return circulation is provided in these installations in the way already described, being even more essential than in small jobs with shorter runs and fewer fixtures; yet one would think that the great number of fixtures served would insure at least one or another being in constant use, and thus keep warm water in the main lines without special provision for the purpose.

In cottages with no bath and with small culinary requirements,

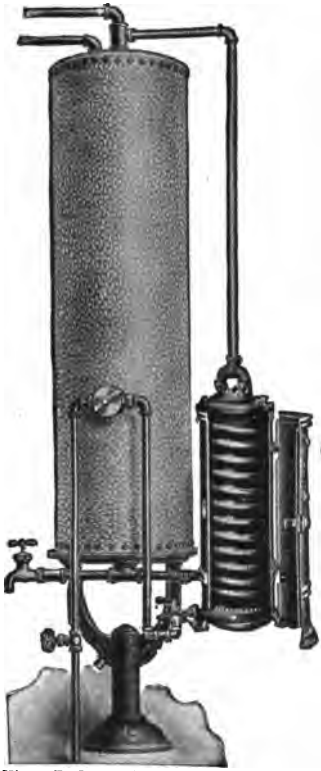


Fig. 17. Crane Gas Heater Connected to Range Boiler Controlled by Thermostatic Valve.

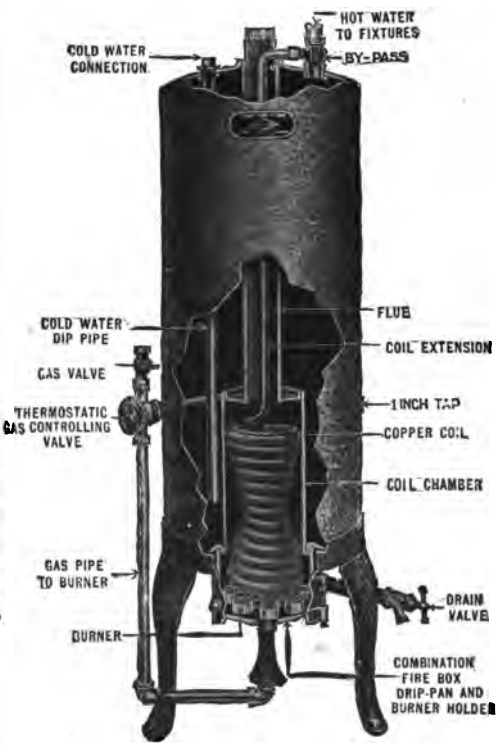


Fig. 18. "Lawson" Combination Gas Heater and Range Boiler Thermostatic Control Valve at Left.
Courtesy of Crane Company, Chicago

a 30-gallon reservoir is sufficient. Not less than 40 gallons should be employed for a bathroom job. The capacity of the average stove heater is even too great for 40 gallons' storage unless there is liberal use of hot water; but where gas is used and the water heating independent of the cooking heat, as it generally is, the temperature can be regulated to suit. A storage capacity of 52 gallons or more is usual for large residences.

Gas Heaters. There are gas heaters provided with thermostatic or pressure mechanism by which the hot service is taken care of automatically. The latter of these are simply connected in the line in a convenient place, and operated by a differential valve. Their appearance is shown in Fig. 16. Simply opening any hot-water faucet reduces the pressure, and the gas is thereby turned on full as

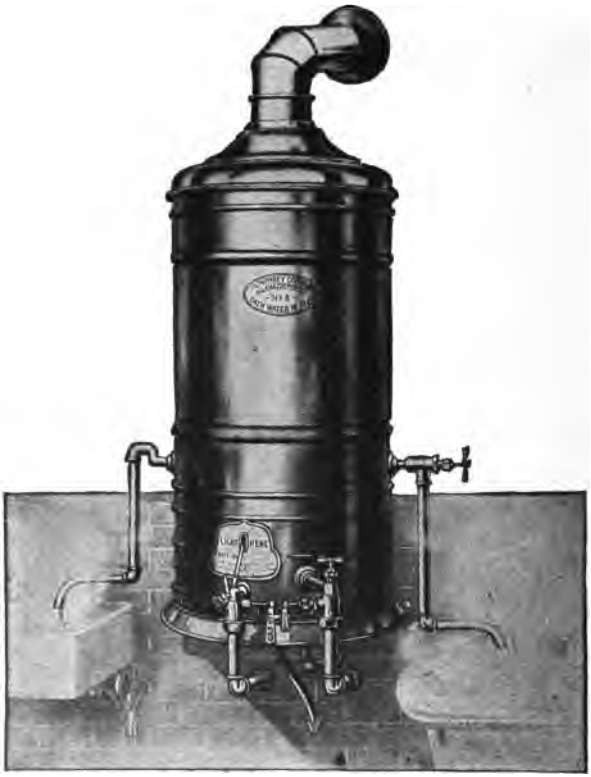


Fig. 19. Instantaneous Gas Heater Connected to Gas Supply Pipe and Operated Directly in Bathroom.
Courtesy of The Humphrey Company, Kalamazoo, Michigan.

long as water is drawn. A pilot light ignites it, and the supply is heated as fast as it passes through the copper coils of the heater. No storage capacity is required by this form. In another form, shown in Fig. 17, the heater is controlled by a thermostatic valve projecting into the regular reservoir used with it. When the water in the reservoir is heated to the desired temperature, the gas supply is reduced or cut off. In Fig. 18 is shown in part section the "Lawson"

combination gas heater and range boiler. This is a very reliable heater and is very well designed. The copper-tube coil forms the direct heating surface, having water connections at both top and bottom of the boiler. The thermostatic valve shown at the left regulates the gas consumption. Drawing water from the hot faucets lowers the temperature in the reservoir through the cooling influence of the incoming water, and the thermostatic principle is again made to serve in opening the gas-valve until the water is heated to the desired temperature.

There are other arrangements consisting essentially of an encased copper coil, above a gas-burner, connected to a standard reservoir at top and bottom. In these, the gas is turned on and regulated by hand as nearly as possible to suit the needs.

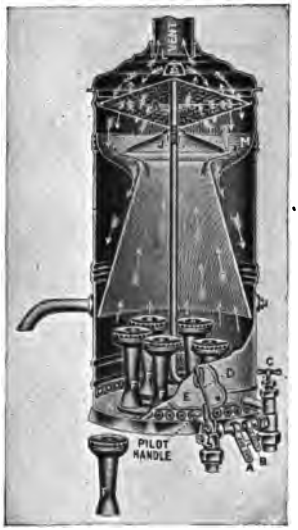


Fig. 20. Sectional View of Humphrey Heater Shown in Fig. 19

Instantaneous water heaters, operated by gas or gasoline, and placed in proximity to the fixtures served, as shown in Fig. 19, so as to deliver the heated water directly, are in general use where local conditions favor them. These have have no storage capacity. A sectional view of Fig. 19 is shown in Fig. 20. In this heater, the water is not exposed directly to the heated air and gases, and water so heated is suitable for use for any purpose so far as the method of heating is concerned. The purposes for which water heated in contact with the gases of combustion may be used are limited.

Other heaters of this class offer admirable means for the water to take up the heat generated by the gas. All of these special means of heating water—especially those not conforming to the plumber's regular routine—are best understood and judged by a close study of the literature supplied by the makers.

Avoiding Lime Deposit. Where lime or other deposits choke the water back and connections as ordinarily installed, both the annoyance and the danger may be avoided by following the plan

shown in Fig. 21, in which the water is heated by water by conduction through a coil in the reservoir. The water back is connected to the coil; and an expansion tank, piped as shown, is provided to take care of the expansion of the water in the primary heater or water back. Distilled water is used in the back to avoid incrustation of the back and connections. *C* is the tank, which must be filled to above the flow connection. *G* is tank return; *D*, the drain to water back and connections; *E*, a sediment cock on the reservoir proper. The flow from upper water back connection to the expansion tank should be at least one size less than either the coil in the reservoir or its connections.

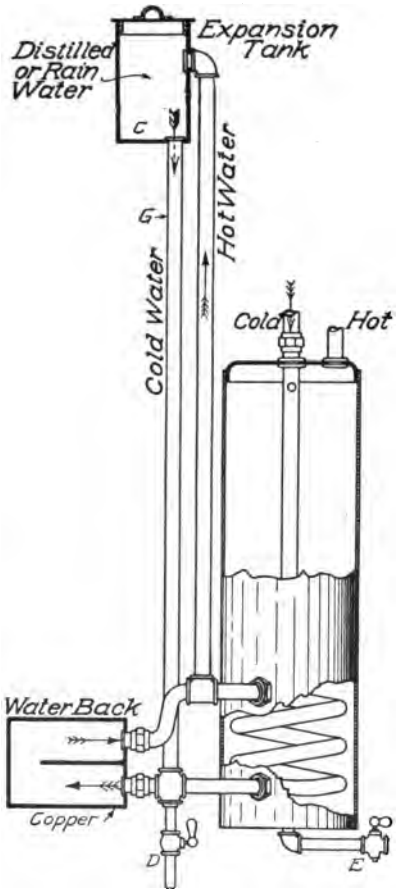


Fig. 21. Reservoir Heated by Hot-Water Coil Connected to Water Back, Avoiding Choking from Lime or Other Deposits

Two Heaters to One Boiler. Occasionally two heaters are connected to one boiler as shown in Fig. 22. In this instance it is assumed that the house is heated from a furnace in the basement and a coil is fixed in the heater, while hot water may be derived from the water back in the range at the same time. This procedure gives a greater volume of hot water and, in a temporary hard-water district, one heater may be put out of action and the incrusted deposit removed without interfering with the hot-water supply derived from the other heater. To accomplish this, however, stop cocks are required on each pair of circulation pipes. Obviously, this is a very dangerous practice and, where adopted, only stop cocks with square heads and loose keys should be used. Further, they should be

tightened in such a manner that it is impossible for anyone other than a proficient authorized person to manipulate them.

Practically the same idea is shown in Fig. 23, where both the water back and independent heater are connected to one boiler. This is very good practice for those buildings requiring an unusual quantity of hot water one day per week and a normal quantity the rest of the time.

Two or More Boilers to One Heater. Where an efficient heater is installed and the storage capacity in the boiler is inad-

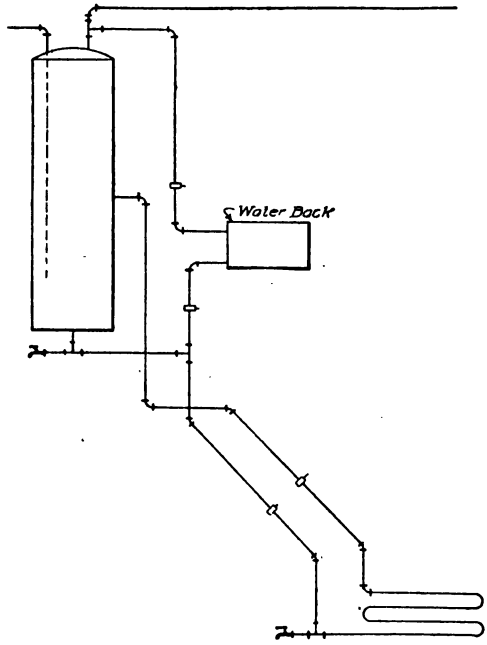


Fig. 22. Layout in Which Two Heaters Are Connected to One Boiler

equate, or in those buildings requiring quantities of water on fixed days out of all proportion with the ordinary demand, two, three, or more boilers can be connected to one heater as shown in Fig. 24. This method is also serviceable in large country houses where one boiler is sufficient most of the time, yet when house parties are held, three times the storage capacity is necessary to insure satisfaction. Stop cocks must be fixed on each pair of the circulation pipes so that one or two of the boilers can be put out of com-

mission when not required. The danger of explosion through the cocks is not so great as in the former method, as all six cocks would have to be closed at one time before the danger zone was reached. However, they should not be tampered with in any way by anyone but a competent person.

Collapsing of Boilers. It is not uncommon for boilers to collapse during the winter months, the chief danger being from

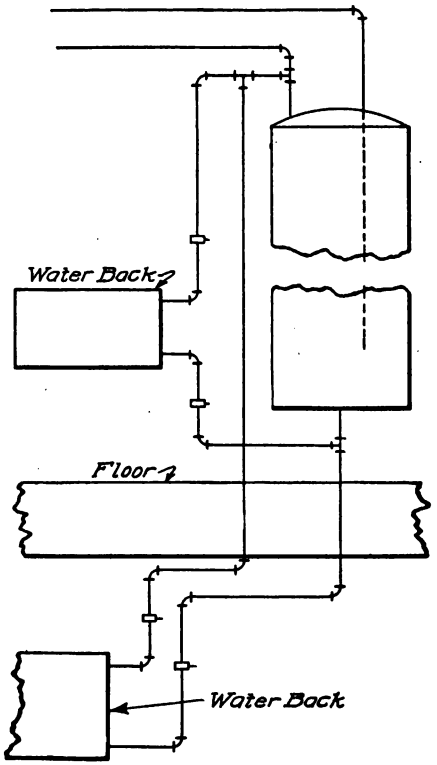


Fig. 23. Layout in Which Water Back and Independent Heater Are Connected to One Boiler

frost. The collapsing of the boiler most frequently happens in the gravity supply where the expansion pipe is discharged into the supply tank, which is oftentimes exposed to frost. The collapsing of the boiler used for domestic hot-water supply may be explained in this manner. During the winter season a large fire is kept in the cooking range, causing the water in the heater

and in the boiler to attain a very high temperature. The water in the heater, circulating pipes, and boiler expands considerably, owing to the increase of temperature, and in expanding rises in the expansion pipe. The water is now frequently emitted in spasmodic spurts from this pipe which is terminated over the

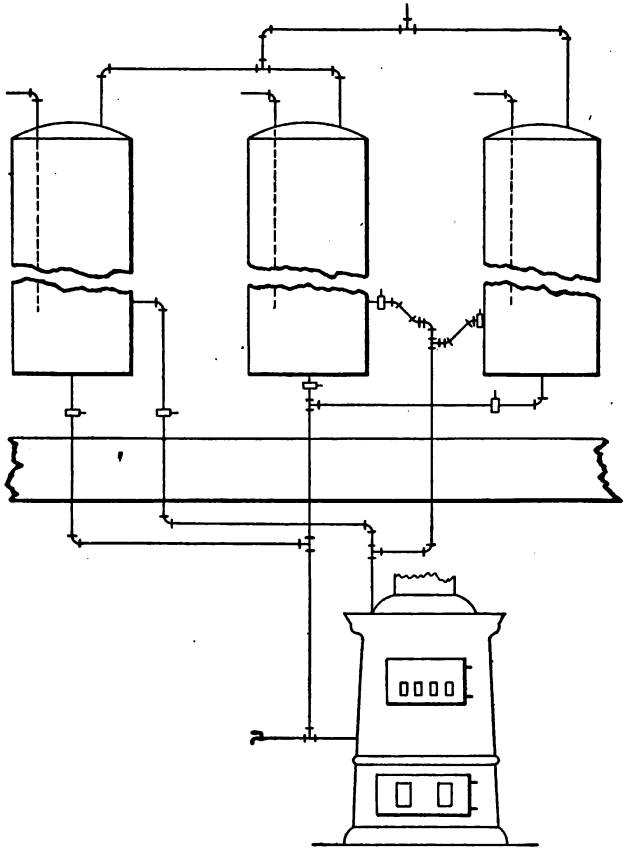


Fig. 24. Layout in Which Two or More Boilers Are Attached to One Heater

tank. It being a frosty night and the tanks being in an exposed position, the water cools and solidifies gradually at the outlet of the expansion pipe, until it becomes hermetically sealed; at the same time the supply pipe to the boiler also becomes stopped by frost. The fire in the heater is now allowed to die out and while cooling the water also contracts both in the heater and

boiler, and in so doing a partial vacuum is formed in the boiler. Now when this reduction of internal pressure takes place, the external atmospheric pressure is such that the material of which the boiler is constructed is not sufficiently strong to withstand the enormous external pressure exerted on the boiler, with the result that the body or sides of the boiler are crushed in or, in other words, the boiler collapses.

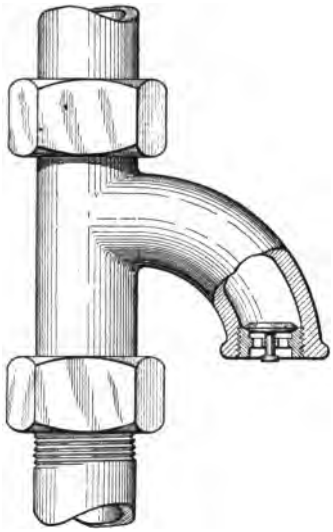


Fig. 25. Vacuum Valve to Prevent Boiler Collapse

Fig. 25 shows a vacuum valve which should be placed in the hot supply pipe to the fixtures, as close to the boiler as practicable. Under normal conditions, the water pressure in the systems keeps the valve closed, but as soon as a partial vacuum forms in the boiler, the external atmospheric pressure of 15 pounds per square inch exerted on the valve opens it and allows air to find its way into the boiler, thus equalizing the internal and external atmospheric pressure, which obviates the collapsing of the boiler.

REVIEW QUESTIONS

REVIEW QUESTIONS

ON THE SUBJECT OF

SANITARY APPLIANCES

1. How can the water seal of a trap be broken by siphonage?

2. Define a mechanical trap and state the advantages it possesses over the ordinary type.

3. What are the essential features of a good bathtub?

4. Which do you prefer for the ordinary type of residence, a solid porcelain or an enameled-iron bathtub?

5. Mention three types of water closets which are better than the hopper and say why they are superior.

6. Which do you prefer, a high or a low tank, to supply a water closet?

7. Sketch and describe a good form of range closet.

8. Sketch, in section, a good form of flushometer.

9. Describe the different types of drinking fountains and their use.

10. What, in your opinion, is the best material for lavatory basins?

11. How are the effects of grease in sink water avoided?

12. How is the flushing of urinals effected?

13. Sketch and describe a good type of pantry sink.

14. In what respect does a slop sink differ from a kitchen sink.

15. Sketch two laundry tubs of modern pattern and show the necessary waste and vent pipes.

REVIEW QUESTIONS

ON THE SUBJECT OF

SEWAGE DISPOSAL

1. Define sewage, bacteria, aerobic bacteria, and anaerobic bacteria.

2. When and where would you dispose of the sewage by dilution?

3. Would you favor chemical precipitation as a means of disposal? Will this method purify the sewage?

4. Describe the difference between a settling tank and a septic tank.

5. How would you dispose of the sewage from a large country mansion where no regular sewers exist?

6. Write a description of the Polk tanks.

7. Do the Greenville tanks differ from other types?

8. What is a contact bed? What essential features would you keep in mind in designing one?

9. What is a sprinkling filter and under what conditions will it work?

10. Describe the Polk filters.

11. Do you recommend sand filters for the purification of sewage? Give their relative advantages and disadvantages.

12. Sometimes disinfectants are used to purify sewage. What disinfectants are used and how are they applied?

13. Write a brief account of the electrolytic treatment.

14. Sketch, in section, a good type of ejector.

15. Where are ejectors commonly used? Is it ever imperative to install ejectors?

16. Explain the working of an ejector.

REVIEW QUESTIONS

ON THE SUBJECT OF

BACTERIOLOGY AND SANITATION

1. Give briefly the process of fermentation of any fruit juice. What is the result of the fermentation?

2. Why will grape juice, when heated and placed immediately in clean air-tight bottles, remain sweet almost indefinitely?

3. Give briefly the work done by Louis Pasteur in developing bacteriology.

4. In what particulars are *solid* cultures an improvement over *liquid* cultures?

5. Show how Koch proved that the bacteria were the *cause* and not the *result* of the disease.

6. Name the three classes of bacteria according to form. Can you put any of the well-known bacteria in the class in which they belong?

7. Are bacteria all harmful? If not, name some useful types and show how they help.

8. In what ways are the noxious bacteria harmful to man?

9. What do you understand by *vital resistance?*

10. Can you give the reason for a person, who has been working hard for some time, taking cold and contracting pneumonia, say, whereas under ordinary circumstances the attack would probably have been confined to a *bad cold?*

11. How many things can you name which will bring about *immunity* from disease in a person?

12. What are the *phagocytes*, and what is one of their important functions?

13. Describe the process of vaccination and show how it originated.

14. Give briefly the method of producing an antitoxin serum for diphtheria.

15. In what ways is the diphtheria antitoxin valuable?

16. What is the difference between the mediaeval and modern attitude toward disease?

REVIEW QUESTIONS

ON THE SUBJECT OF

INFECTIOUS DISEASES, DISINFECTANTS, GARBAGE DISPOSAL

1. What are the chief means of disseminating diphtheria and enteric fever? Describe the precautions to be taken in an epidemic of either.

2. Give a list of the infectious diseases likely to become epidemic in any district; explain fully the symptoms of a person suffering from smallpox or scarlet fever.

3. How may tuberculosis be transmitted from one person to another? Mention the method or methods you would adopt to prevent or check the spread of the disease.

4. How would you check the spread of summer diarrhoea? Do you consider the disease infectious?

5. How are the following diseases transmitted: anthrax; cholera; diarrhoea; scarlet fever; tetanus; and grip?

6. What diseases may be brought about by polluted water, defective sewers and drains, and overcrowding and insufficient ventilation?

7. Explain the following terms in detail: deodorant; antiseptic; disinfectant; fumigation; and saturated steam.

8. A bedroom in a brick house has a capacity of 15,000 cubic feet. How would you disinfect the room and its contents after scarlet fever?

9. Which do you prefer for disinfecting purposes, dry or moist heat; superheated or saturated steam?

10. How would you proceed to disinfect a drainage system where persons had been suffering from enteric fever.

11. State the advantages of the water-carriage system over the conservancy system.

REVIEW QUESTIONS

ON THE SUBJECT OF

STEAM AND HOT WATER FITTING

1. What points should be borne in mind when selecting a heating boiler for a given service?

2. Explain by an example how to check the catalogue rating of a boiler.

3. Point out the difference between (a) direct, (b) direct-indirect, and (c) indirect radiation.

4. State the advantages of each type.

5. What advantages do overhead coils possess over other classes of direct radiation?

6. (a) With overhead coil heating, how should the coils be placed with reference to walls and floor to secure the best results? (b) Why?

7. In what two ways is heat given off by a radiator?

8. What advantages has a wet return system over one with dry returns?

9. (a) In what classes of buildings, as a rule, may the overhead feed system be used and why? (b) What advantages are possessed over the up-feed system?

10. When should a two-pipe system be used in preference to a one-pipe?

11. Explain the action of a siphon trap in balancing a low pressure steam heating system.

12. When is it advisable to establish an artificial water line?

13. Explain in detail how to compute the radiating surface for low pressure steam in a corner room 18 ft. square, 10 ft. high, the exposed wall to be 16 in. thick, exposed toward the north and west, and having glass surface equal to one-fourth the total exposed surface of wall and glass combined.

14. Describe the action of aspirating heaters. To be most effective in causing a rapid flow of air in a flue, at what point should they be placed?

REVIEW QUESTIONS

ON THE SUBJECT OF

DOMESTIC HOT-WATER SUPPLY

1. Define conduction, radiation, and convection.

2. What causes hardness in water, and what material will prevent this lime or incrusted deposit taking place?

3. Mention all the types of heaters with which you are familiar. State when you would recommend each type.

4. Is there any material difference between the street pressure and the gravity systems of supply? Make a sketch of each.

5. What do you understand by the term *secondary circulation?* When and where would you adopt it?

6. Why is it necessary to use an expansion pipe with a gravity supply and not with a street pressure supply?

7. What size of circulation pipes would you use with a temporary hard-water supply?

8. Mention the material you would use for the entire apparatus with soft water, temporary hard water, or permanently hard water.

9. Is there any system you could furnish to obviate all nuisances from a temporary hard-water supply?

10. Discuss the advantages and disadvantages of the double-boiler system of supply.

11. When and where would you use a steam coil? What advantage does it possess over other methods?

12. When would you recommend instantaneous gas heaters as the best method of supply?

13. Show by a sketch how you would connect three heaters to one large boiler.

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